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VOL. 16 NOVEMBER, 1926 No. 5

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Discussion of all papers is invited

VOL. 16 NOVEMBER, 1926 No. 5

WATER SUPPLY AND MAIN DRAINAGE DISTRICTS

BY CLEMENS HERSCHEL[1]

"'Every gentleman ought to know a little of law,' says Coke, and perhaps, say we, the less the better." Thus begins that ponderously humorous, early Victorian tome, called: "The Comic Blackstone," by Gilbert Abbott à Beckett; and following its exhortation, let us see whether gentlemen hydraulic engineers may not somewhat inform themselves on a branch of the law which lies at the very foundation of their comfort and success, when designing and constructing certain works that are within their especial province to create.

DISTRICT UTILITIES OF MODERN ORIGIN

Fundamental difficulties in such work, due to the law, are of quite modern origin. There were practically none, so long as municipalities, or else private water companies, built the desired water supply or drainage plant. Adventurers of this sort of undertakings had credit. Ordinarily they could be, and were, endowed with rights of eminent domain (powers of condemnation) by the legislature, and with a sufficiency of these two handmaidens, most anything could and can be accomplished. Trouble only arose when it became a question of catering to the needs of groups of municipalities in congested districts. But as such groups or districts may be expected to

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crystallize in ever increasing number, a study of the means requisite for their relief is not without its present and general uses.

Such groups or districts have no credit. They are not known to the world of finance. They have no financial standing, as districts, whatever; at least not until a kind legislature,

> in a fine frenzy, rolling . . . .
> Turns them to shapes, and gives to airy nothing
> A local habitation and a name.

IMPORTANCE OF PROCEEDING UNDER A TRIED AND RATIONAL ACT OF THE LEGISLATIVE POWER. THE MASSACHUSETTS ACT OF 1895

So that to do business, they must first be properly constituted;—created, as it were. Much depends on such act of creation, as we shall see.

Naturally; yet has little thought at times been given, apparently, to the attributes and endowments which the new creature must have, to be able to exist in comfort and to act with efficiency.

A simple case is that of the Metropolitan Water Board of Massachusetts, created by Chapter 488, Acts of 1895. "The Great and General Court," of Massachusetts, has no restrictions put upon it, of the extent to which it should invoke, for public purposes, the credit of the State. Consequently, when it decrees, Section 1, that certain citizens shall "constitute the Metropolitan Water Board;" Section 2, that "said Board, acting for the Commonwealth, shall construct, maintain, and operate, ... and shall provide thereby a sufficient supply of pure water" for certain designated cities and towns; and Section 17, "the treasurer and receiver general shall, from time to time, on the request of said board, issue negotiable bonds;" the main spring of the machinery requisite for causing such water to flow, has been wound up; and the rest is a matter of detail.

Historically, it may be added that some 20 towns and cities, being Boston and bailiwicks adjacent, are today supplied in wholesale quantities from the works which are the outcome of those begun by the Metropolitan Water Board of 1895; these towns paying per million gallons delivered to them, and distributing to their respective citizens; and the main drainage or sewerage of the same territory was built, and is operated, by practically the same authority. Topographically, the territory served, is essentially of the same nature, as the similarly situated territory along the sea coast adjacent to Man-

hattan Island, in New York and New Jersey. Coal and iron, being important elements of the coast of such works, are, however, dearer, for obvious reasons, in Massachusetts, than they are in New Jersey; but the average cost of water delivered in the Massachusetts Metropolitan District has always, nevertheless, been in the vicinity of only $50 per million gallons, delivered within the boundaries of the purchasing towns.

THE SITUATION IN NEW JERSEY

Compare all of this with the horrid example that New Jersey has furnished these forty years.

Its history commences with the endeavor of certain well meaning and enterprising men to procure a charter about 1884 to do in New Jersey what later the Metropolitan Water Board did in Massachusetts. It should be remembered, in this connection, that the business of supplying water to municipalities, has for long been the subject of debate, whether it be a governmental function, or a business enterprise. Quite recently high administrative authority,—the United States Internal Revenue Bureau,—decided that when a city or town undertook such work, it went into business; and that consequently its employees for that purpose were under the obligation to pay an income tax upon their salaries; while its employees engaged in governmental functions, were exempt.[2] There is, to be sure, a school of political economists, who for long have held, that cities alone should supply the water consumed in cities.

If they had their way, it may be argued, then bread and cakes, the morning bottle of milk, yea, the contents of the coal hod and all that it fructifies and what not besides, would likewise be supplied by municipal effort. Still, there appears to be no axiomatic reason, why all such work, including the supplying of water to municipalities in wholesale quantities, by them to be distributed to their inhabitants, should not be the subject of private enterprise. Especially, when, as has since become the universal practice in the United States, corporations doing such service are made subject to the supervision

[2] A news-item of August 17, 1926 (after this article was written,) stated that by a decision of the "Board of Tax Appeals," this ruling had been reversed. Whether or no such revision is the decision of the court of last resort, remains to be seen. Nor does it affect the principle, that for municipalities to supply water, may be considered an undertaking outside of their governmental functions.

of State Utility Commissions. At all events, so thought certain parties in 1884, as regards the wholesale supply of water to the towns and cities of the Metropolitan District of New Jersey. But a charter containing the essential element of rights of condemnation, given as a matter of course, as it were, to every city or village water supply company, or to the municipality itself, was denied them.

Nothing loath they went ahead in 1889, without such a charter. The super-optimistic view of their principal New Jersey counsel, which caused them to do this, may be gleaned from his remark, made one day, that when he wanted anything in New Jersey, he sent out and got it; which probably operated well enough nine times out of ten, but failing on the tenth time, might be enough to wreck any enterprise.

The present writer had such fears when undertaking the work. It was undertaken with the expectation of making it his life's work but he has not now and never had, a dollar's worth of pecuniary interest in it; and since September, 1900, has had no connection with it of any kind; hence can today discuss it dispassionately. His only contact with that enterprise since 1900 has been acting as one of three referees, in an arbitration, at which time he represented a contractor having a claim against the company; and later, one of three appraisers to appraise the value of the company's property, at which time he acted for the City of Newark and was Chairman of the Committee.

But to resume our historical narrative. September 24, 1889, a contract was entered into by the parties that have above been referred to, agreeing to procure and deliver water to the City of Newark, of specified quality, at a specified pressure, on or before May 1, 1892, up to 27½ million gallons daily; up to 50 million gallons daily by September 24, 1900, when the works were to be handed over to the city; the original plan of the Company having been, to build up a wholesale water supply business between May 1, 1892, and September 24, 1900, from sale of the available margin of 22½ million gallons daily; and by means of other works yet to be built. All of the contract dates and deliveries were complied with, but it required the exercise of Newark's rights of eminent domain to accomplish this; and by the time Jersey City was dealt with, the named adventurers had dwindled in standing to the status of mere financial backers of an individual contractor.

Since then they have sold water to various parties, public and pri-

vate, but have kept in being, one may say, not a shred of the original intent; because it was impracticable for them, as they are constituted, to supply the Metropolitan District with water in wholesale quantities. Without the right of eminent domain, it has been difficult for the Company to continue to exist at all, or properly to deliver water; and as for popularity, or appreciation of good work done, under the circumstances stated, it could not be built up at any time to any noticeable degree.

CONSERVATION

To make confusion worse confounded, now enters on the scene the much abused idea of "conservation;" the favorite child of a forester, with whom it has a perfect application; but which has been extended by its votaries to all, what have been termed, "natural resources." But these exist only that they may be utilized; not hoarded. A forest must be conserved or else it will speedily pass out of existence; but to apply the same treatment to water power, sources of domestic water supply, to mines or the like, is hurtful to the body politic; as the experience of the United States with water power, for some ten years bringing to pass a total cessation of water power construction, did demonstrate abundantly.

No less grievously did this misapplied policy leave its mark on New Jersey water supply legislation; halting progress, confusing enactments, clouding the issues that should have been cleared up; until today the feeling has become general, on a subject not much ordinarily considered, that reform is necessary.

THE PASSAIC VALLEY DRAINAGE LEGISLATION

By Pamphlet Laws, 1902, p. 190, an attempt was made to create a sewerage district, for the purpose of removing the sewage of cities in the Passaic Valley in channels other than the river; become foul, by its use as a sewer beyond decency, not to mention healthfulness.

71 New Jersey Law, p. 574, put rather a quietus on this first attempt in New Jersey at such district work; though the exact meaning of the Court's decision has ever since and is still a matter of disagreeing opinion among lawyers.

Said the Court (March, 1905): "If, for instance, as was suggested by the arguments before us, powers adequate to the execution of the legislative scheme of drainage were conferred upon the entire area to

be taxed, and duties respecting the exercise of such powers constitutionally imposed in such manner as indicated that their exercise was compulsory, a question not touched upon in this opinion would be presented." Apparently this invites the interested parties to try again, but having heed to the strictures upon the Acts ruled upon in the opinion. Be that as it may; this was not done. Instead, the legislative draftsman, fertile in expedients, chose to disregard successful precedents, and as has been said elsewhere, apparently "instigated by the devil," devised a new and novel scheme of finance, which is no doubt unsurpassed anywhere as to the delays of execution and the consequent extravagant cost of the works it attempts to construct. Briefly described, it endeavors to use the respective credits of the municipalities concerned, by endeavoring to associate them in a voluntary partnership, having a commission as its mere commercial or executive agent.

Twenty years of experience has since shown the worthlessness of such a plan of action. The several partners change their moods and nature from year to year; unanimous action of these partners is frequently needed; grievous delays result; works that should be completed in 4 or 5 years take 20 to build; their cost is a multiple of what it should have been. Notwithstanding such experience had for some ten years in the case of the Passaic Valley Drainage Commission, when it became a question of supplying with water a group, or groups, of cities in the northern part of the State, the same general plan of legislation was repeated; see Chapter 71, pamphlet laws of 1916; and ten years of experience with that act, has not changed the results found during the preceding ten years with the operation of the similar Passaic Valley Drainage Act.

Is there any proof that New Jersey water acts do not operate efficiently? There is. It has been noted above that in the less favorably situated Metropolitan District of Massachusetts the cost throughout, of water delivered for distribution to the inhabitants, has, from the beginning in 1895, been about $50 per million gallons delivered. In the Metropolitan District of New Jersey this same average price never was in the vicinity of $50, and is now not less than about double that figure; about $100 per million gallons. Water is not sold for less than that in New Jersey, because the water supply works are not built by properly constituted organizations. It costs too much to produce it; more especially within the Metropolitan District. The time has gone by when this can be done in closely limited quantities,

supplying single municipalities. It must, henceforth, if some approach to thrift and economy is to be attained, be done for this District collectively; and by a Commission having a sound financial standing appurtenant to itself. Also having clear and ample powers of initiative, to be exercised in behalf of the municipalities that need the water.

GOVERNOR SILZER, AND WATER POLICY HISTORY IN NEW JERSEY SINCE 1923

Governor Silzer was the first member of the New Jersey State Government to recognize that the existing water situation in the Metropolitan District could not with safety be allowed to continue. In a speech at Newark, November 8, 1923, before the New Jersey State Chamber of Commerce, he gave a full and able review of the emergency present, and means that might be adopted to remedy it. Whether, in calling for auxiliary action from the New Jersey State Chamber of Commerce he did not—as the saying goes—and despite of its high sounding title, "put his money on the wrong horse," is a debatable question. No doubt it was done in an endeavor to take the subject wholly out of politics; surely commendable in itself. But neither the legislature of 1924, nor that of 1925, received any aid towards reform legislation from the Committee of this body, appointed to advise the Governor, Senate and Assembly.

Upon this, by Joint Resolution 8 of 1925 practically this same Committee was made a "State Water Policy" Commission; $35,000 was given it; it was instructed to present "the formulation of a comprehensive State *Policy*, with reference to the development of the waters of the State, the recommendation of the instrumentality or instrumentalities through which such *Policy* should be carried into effect, and the ways and means of financing thereof."

One would have thought that on a subject of such importance to so large a territory, public hearings would have been advertised and held in at least the two large, principal cities of the State. Nothing of the kind was done, however, and the only public hearing ever held, was given by the Senate Committee on Revision and Amendment of the Laws, at the very end of the Special Session of 1926 about to be referred to. Instead of a "formulation of a policy" the Commission went out of its way to argue about whence certain water supplies were to come, a subject it was in no way instructed to consider, and

by what system of works they should be supplied; the usual form of a constructing engineer's report.

The Joint Resolution further says: "The Commission shall report to the next session of the Legislature with drafts of bills to effectuate its recommendations." But no draft of a bill accompanied the report of the Commission; and their report, instead of being presented in time for the Governor to refer to in his Inaugural Message, was presented so late in the session, that it could not then be properly considered. The Legislature of necessity was forced to vote to consider it in a Special Session called for the purpose; but even then was compelled by the described lack of compliance with the instructions given the Commission by the Joint Resolution of 1925, practically to refer the whole subject to the Legislature of 1927.

Nor had anything been submitted as to the "ways and means of financing" a selected State water "policy;" "the very head and front" of the situation's offending.

THE WAY OR WAYS OUT FOR NEW JERSEY

Some way must be found to build, in the Metropolitan District of New Jersey, in a rational manner, the public utilities which the District already needs; and in greatly increasing volume, shortly will need.

1. One way would be to amend the eighty-two-year-old Constitution of the State, practically intact since it was passed, and beyond amendment save by legislative action for two successive years, followed by a referendum of the whole State at an election especially called for the purpose.

The initiatory step of such procedure was taken at the 1926 Special Session.

2. Another way would be to have the people of the entire State, by referendum, authorize the issue of bonds, sufficient in amount to enable a District Commission to have financial standing and initiative. Would such a vote be given understandingly? It would be a formidable undertaking to endeavor to bring this about.

3. Form a Metropolitan Utility District with the duty of supplying water to, and removing sewage, from the District, etc., with defined powers of charging and collecting for services rendered; either (3a) under the present Constitution; or (3b) under the Constitution as amended under 1 above.

3a. As above noted, this need not necessarily be taken to be the equivalent of taxation. Such services rendered the public, may be considered, if one wishes, as outside governmental functions. Presumably, the municipalities within the District could organize a stock company to do such commercial work, and the company could borrow money, and carry on its business.

Indeed, we have the precedent of the Port Authority of the Port of New York, a bi-State concern, doing just this thing. March 8, 1926, it went into the open market for 14 million dollars, 4½ per cent Gold Bonds, and had the same oversubscribed on that day in a few hours.

The security back of these bonds is merely the promise of the Port Authority (in the language of its advertisement) "to establish and maintain adequate tolls and charges for the operation and maintenance of the bridges (yet to be built—C. H.) payment of interest and principal and payments to reserve fund, and the performance of this duty may be compelled by any Court of competent jurisdiction upon application by any bondholder." Surely the Metropolitan District of New Jersey, once properly created, could secure its Water Bonds by a covenant stronger and nearer to sound sources of revenue,—the sale of water to municipalities,—than that.

3b. Form such a Metropolitan District by legislation now; which good lawyers of New Jersey say is entirely feasible; or

3c. Form it following, in about two years from now, the passing, if it passes, of the Constitutional Amendment as voted in 1926, by Senate Concurrent Resolution No. 11.

THE CALIFORNIA MUNICIPAL UTILITIES DISTRICT ACT OF 1921, CHAPTER 218

For action under either 3b or 3c, New Jersey has sound precedent in what is now going on, on the East Shore of San Francisco Bay in California.

In 1920, the cities on the East Shore of the Bay of San Francisco, California, were in a predicament as regards their water supply, which was a perfect parallel to that in which are now the towns and cities of the Metropolitan District of New Jersey. It was plainly to be seen that the public and private water companies supplying them, were carrying a burden too heavy to long continue to be thus borne. The wants of these municipalities needed to be assuaged collectively,

not singly, or by each one acting for itself. Upon which, certain public spirited citizens had passed Chapter 218, acts of 1921; and when in 1924 the expected crisis came, nine of these cities immediately organized under the 1921 Municipal Uutilities District act, and are now building a 35 million dollar public water supply. Let me add that the bonds issued by their "East Bay Municipal Utilities District," have been fully sustained, as to their validity, in the court of last resort, 239 Pacific Reporter, p. 38.

Some thoughts on what should be the form and contents of an act modeled after the California Municipal Utilities District act, may not be amiss at this point.

a. 218 of California, 1921, is a general act. 488 of Massachusetts, 1895, is a special act. Some states may never have more than one district requiring for well being and economy, a district utility law.

b. 218 of California, 1921, is long drawn out on the subject of the formation of the District. A wonderful scheme is detailed, by means of which the cities vote and determine whether or no to be of those comprising the District that is to be.

488 of Massachusetts hardly touches upon the subject. It names 13 cities and towns, possibly consulted previously in private upon the subject, and decrees that they, and others whose subsequent joining the District is provided for, "shall constitute the Metropolitan Water District."

c. Both the Massachusetts and the California act are refreshingly brief, but to the point, on what forms such a stumbling block in New Jersey; the question of finance.

The essence of the Massachusetts provision on this point has been quoted above, but will bear repeating.

"SEC. 17. The treasurer and receiver general shall, from time to time, on the request of said board, issue negotiable bonds in the name and behalf of the Commonwealth," etc.

And the California statute, Section 12, says:

"Any municipal utility district incorporated as herein provided shall have power; . . . .

"Eighth: To borrow money and incur indebtedness, and to issue bonds," etc.

As was said above; the rest is a matter of detail. Once form a Metropolitan District, and provide it with funds to work with, and it

would be a lot of officials poor in spirit and abilities, indeed, which could not then do its duty efficiently. In New Jersey such officials have been called upon these 20 years to "make bricks without straw;" and great have been their delinquencies from an economical and efficient procedure, in consequence.

It is hoped that this exhibit, historical and legislative over a wide range of our country and in point of time, will thus prove of general interest, though more especially where congestion of population has made the formation of a municipal utility district, necessary or desirable.

A CEMENTED GRAVEL SLAB—VITRIFIED CLAY PIPE DISTRIBUTION SYSTEM FOR RAPID SAND FILTERS[1]

By Harry N. Jenks[2]

INTRODUCTORY REVIEW

Of the many problems arising from the varied nature of the processes involved in the progressive purification of the water as it passes through a rapid sand filter plant, the two that have to the greatest extent engaged the attention of designers are the adequate and economical coagulation of the water, and the thorough and uniform washing of the filter units. This paper has for its object a consideration of the solution of this latter problem by means of a new filter bottom designed by the speaker, and now in successful use at the Sacramento, California, filtration plant.

Because of the prime importance of the operating function of the filter underdrains, the problem has always been that of designing the filter bottom as an efficient and economical distribution system for the wash water. During the early stages of development, the distributing manifold appeared, with strainer plates, blocks and holding-down screens. On the whole, these designs were productive of good operating results, but their expense, both in construction and maintenance, indicated a need for simplification. In answer to this need, perforated pipe filter underdrains were first devised and installed at Harrisburg (1). Although during the succeeding years many designers were reluctant to depart from the more elaborate means of securing a uniform filter wash, and several commercial types of filter bottoms claimed some recognition, yet in general the distribution in metal by means of simple orifices in pipes has come to be regarded as standard practice.

[1] Presented before the Water Purification Division, Buffalo Convention, June 9, 1926.

[2] Associate Professor of Sanitary Engineering, Iowa State College, Ames, Iowa; formerly Superintendent, Pumping and Filtration Works, Sacramento, Calif.

Confirming and extending Charles G. Hyde's experiments at Harrisburg, the writer investigated in 1920 the hydraulic characteristics and the efficiency of the perforated pipe underdrain system (2), under the direction of Mr. Hyde, who was then chief consulting engineer in charge of the design of the present Sacramento pumping and filtration works. Shortly before the completion of the plans for the filter units, favorable reports were received of the operating results obtained by James W. Armstrong through the use of slat bottom underdrains in one of the Montebello filters (3). Accordingly, the plans and specifications for the Sacramento plant were made to provide for the installation of perforated pipe underdrains in the south group of four 4-m.g.d. filter units, and of wood grating underdrains in the corresponding north group.

The experience with wood grating underdrains in the Sacramento filters, as reported in 1925 by the speaker (4), was made the subject of a symposium by a number of water works engineers interested in the problem (5). It appeared from the discussion that no great improvement, if any, might be expected over the standard perforated pipe system, through the installation of wooden false bottoms. Moreover, the use of a top layer of cemented gravel to prevent the penetration of sand into the gravel bed, which had been tried at Sacramento in accordance with experience at Toronto and elsewhere, was considered to be of doubtful advantage.

Holding in review the general and particular requirements of operation, it is apparent that if a filter underdrain system is to approach the ideal case, it should constitute an effective distributing medium for the wash water, should serve as a dependable support for the overlying sand bed, and should entail the least possible expenditure of money for construction and maintenance. It is generally conceded that the first requirement is most nearly fulfilled by perforated pipe underdrains in conjunction with a deep graded gravel bed. The second requirement, under certain conditions, has been successfully met by providing a cemented top layer of gravel. Finally, the advantage of low cost is undoubtedly to be found in the false bottom type of underdrain, using a wood grating.

None of the accepted types of underdrains, however, possesses collectively and to the same degree the advantages of each one individually. Because of this fact, coupled with a situation at the Sacramento plant that in effect demanded a filter underdrain system exhibiting all the characteristics just outlined, the speaker felt en-

couraged to attempt an original design that should conform as closely as possible to these requirements.

At the outset, it was determined that the following principles should be embodied in the anticipated design:

(1) The primary distribution of wash water through orifices in a closed system
(2) The full utilization of the advantages of a porous medium such as cemented gravel,
  (*a*) To prevent the penetration of filter sand into the gravel bed and underdrains, and
  (*b*) To serve as a secondary diffusing medium for the wash water.
(3) The entire system to be as inexpensive as possible in construction, operation, and maintenance.

I. CONCEPTION OF NEW PRINCIPLES OF DESIGN

After much thought on the subject and many trial groupings of the different elements involved, the speaker, on July 6, 1925, conceived the idea of a cemented gravel slab—vitrified clay pipe underdrain system as an integral part of the bottom of a rapid sand filter. This conception of a filter bottom led through various stages of experimental development to the practical design and operation of the present full size installation in the Sacramento filter plant.

The essential component parts of this design are shown in figure 1. They comprise a system of wash water laterals made of perforated standard sewer pipe; suitable waterways underneath the laterals; and a cemented gravel slab poured monolithically between and over the underdrain system, and bonded directly to the structural floor of the filter unit. The sand bed rests directly on the porous slab without any intervening graded gravel layers.

Heretofore, the outstanding disadvantage of cemented gravel has been its structural weakness in connection with the common conception of its use as a sort of crust on top of the usual graded gravel bed. Thus there is always a tendency for failure to occur in bending, the porous layer acting as a beam or slab under upward water thrust. The new idea, embodied in the present design, once for all obviates this frequent cause of failure, by eliminating bending action entirely. The gravel slab being bonded to the structural floor slab of the filter, the stresses induced by the passage of the wash water through the cemented gravel are those of direct tension and shear only. This constitutes a new principle in the case. Even

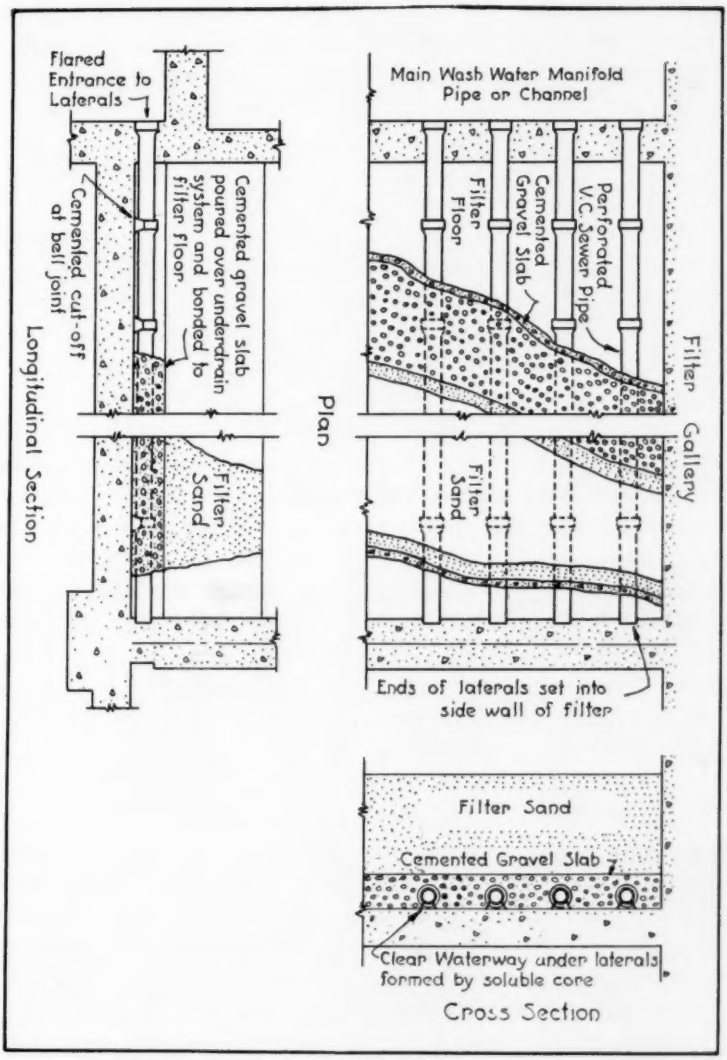

Flared Entrance to Laterals
Cemented cut-off at bell joint
Cemented gravel slab poured over underdrain system and bonded to filter floor
Filter Sand
Longitudinal Section
Plan
Main Wash Water Manifold Pipe or Channel
Filter Floor
Cemented Gravel Slab
Perforated V.C. Sewer Pipe
Filter Gallery
Filter Sand
Ends of laterals set into side wall of filter
Filter Sand
Cemented Gravel Slab
Clear Waterway under laterals formed by soluble core
Cross Section

FIG. 1. TYPICAL INSTALLATION OF JENKS RAPID SAND FILTER BOTTOM EMBODYING THE USE OF PERFORATED VITRIFIED CLAY PIPE UNDERDRAINS EMBEDDED IN A CEMENTED GRAVEL SLAB BONDED TO THE STRUCTURAL FLOOR OF THE FILTER UNIT

in the absence of definite tests that were subsequently made, it was obvious that porous gravel possesses much more strength in shear and direct tension than in flexure.

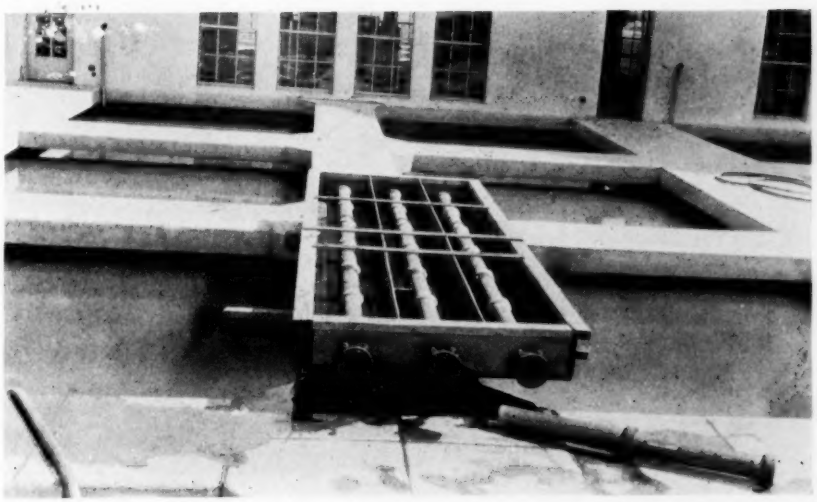
The next step in the outworking of the new design was suggested by the thought that, since the gravel slab would be on the filter floor, the logical place in which to install the wash water laterals would be to embed them bodily in the slab. A practical construction difficulty was overcome here, through the use of rock salt as a soluble core to form the required waterway under each lateral. It was also experimentally determined that the travel of the wash water in the gravel slab on each side of the laterals fully equaled the depth of the slab, and it was further found that the water closed over the top of each lateral and emerged evenly over the surface of the slab with only a nominal thickness of slab.

The fact that the laterals are embedded in the gravel slab renders possible the use of classes of pipe that otherwise might be mechanically unsuited to the internal water pressures involved. Accordingly the speaker determined that it would be entirely appropriate to use common sewer pipe. In addition to cheapness of cost, this pipe has a number of other advantages in this connection. It may be readily embedded in the slab and constitutes a piping installation that will never corrode or wear out, no matter what type of water may be filtered. Furthermore, the bell joints of the pipe afford suitable clearance above the floor of the filter and permit a cemented cutoff to be made at each joint along the waterway below each lateral forming in addition an anchorage integral with the gravel slab itself.

The installation of this kind of filter bottom as a whole, places the construction in the hands of the same men who do the structural concrete work on the filter unit itself. Permitting, as it also does, the employment of the same class of materials and equipment, the labor costs for this distribution system are substantially less than for any other existing type of design.

Nevertheless, as the proposed design represented such a radical departure from all precedent, it was fully realized that nothing short of exhaustive tests on an experimental scale, followed by successful operation of a full size filter unit, would serve to establish the claim for recognition it was hoped that the new type of distribution system might merit.

Opportunity having been afforded of completing all the necessary experimental work the speaker has just referred to, the new ce-



A

B

FIG. 2. EXPERIMENTAL FILTER BOTTOM

A. Box ready for pouring cemented gravel slab. Note perforated sewer pipe in foreground

B. View showing installation of cemented gravel slab nearly completed

mented gravel—vitrified clay pipe distribution system was installed in Filter No. 5, one of the 4-m.g.d. units of the Sacramento plant. The notably satisfactory results that have characterized the routine operation of this filter during the past five months, furnish gratifying proof of the inherent soundness and the practicability of the new design.

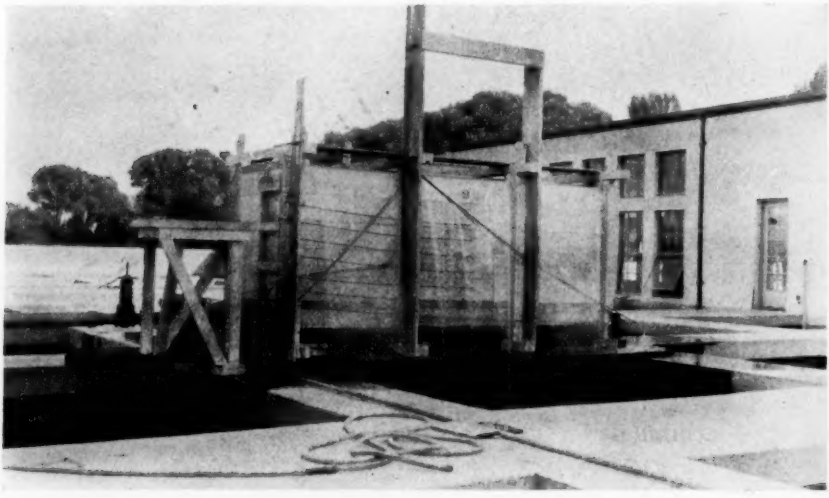
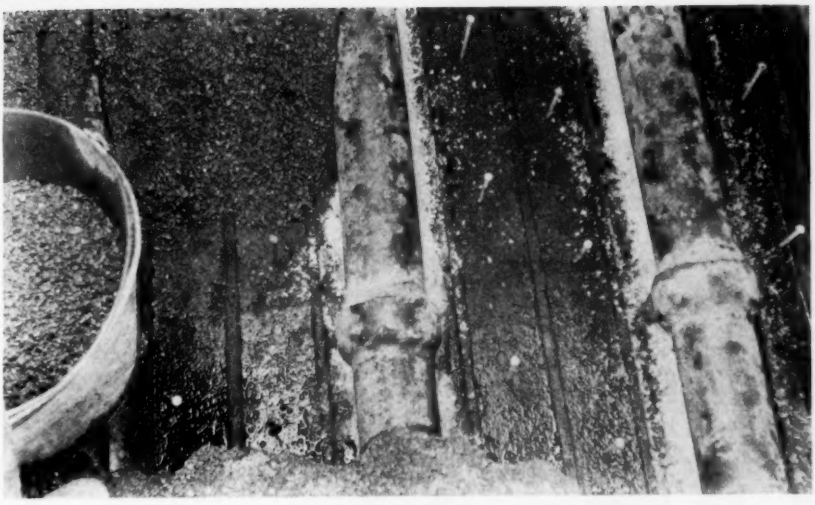


FIG. 3. EXPERIMENTAL FILTER EQUIPPED WITH CEMENTED GRAVEL SLAB—VITRIFIED CLAY PIPE DISTRIBUTION SYSTEM

II. STUDIES OF WASH WATER DISTRIBUTION

Arrangement of experimental filter

In carrying on the tests for wash water distribution, a shallow redwood box was used to inclose the filter bottom, the sides of which were eventually built up to a height of 4 feet above the top of the cemented gravel slab, to form the experimental filter proper. The box represented closely a section from a filter of the Sacramento plant, taken between adjacent wash water gutters, the length of the box being equal to the width of the filter bed. The underdrain laterals installed in the experimental filter could accordingly be made of the same size and length as those found in the full size unit. The apparatus was located conveniently on the walkway over the



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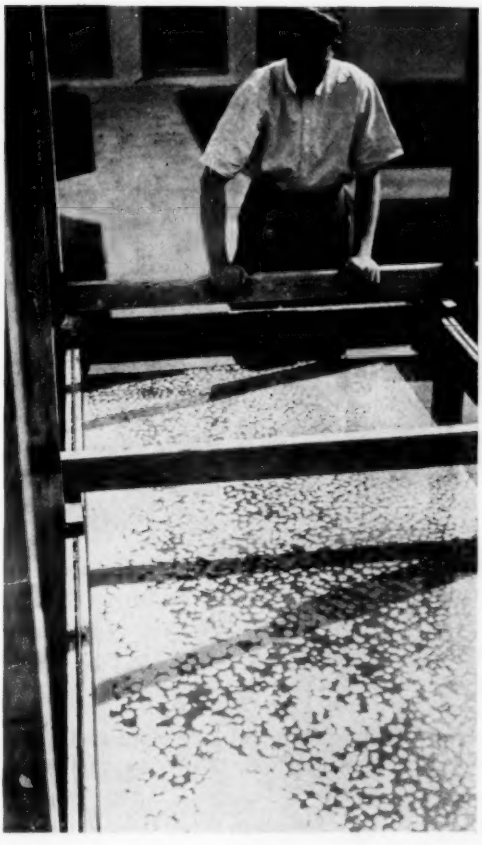


B

FIG. 4. EXPERIMENTAL FILTER BOTTOM

Photograph was taken during washing of filter. View showing replacement of portion of cemented gravel slab to correct inequality of wash. Uniformity of wash demonstrated by even distribution of sand craters, imparting a mottled appearance to the surface.

division wall between two of the Sacramento filters, as shown in figure 2. Wash water and air were available from nearby supply

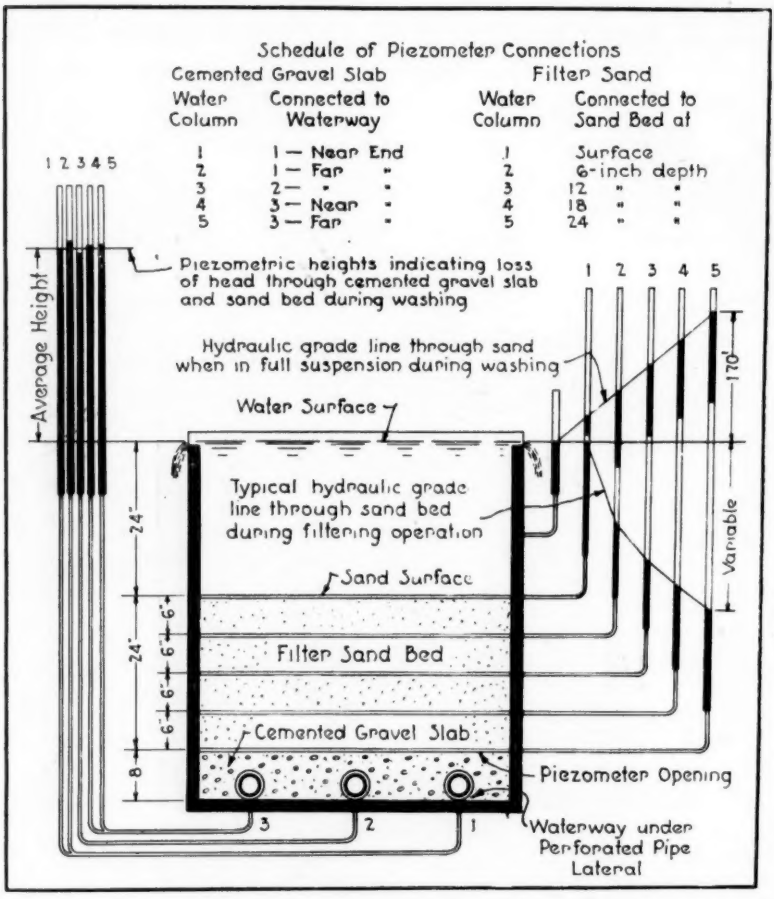


FIG. 5. DIAGRAMMATIC ARRANGEMENT OF PIEZOMETER CONNECTIONS USED IN HYDRAULIC MEASUREMENTS

Note: At each sand bed depth, piezometer openings consisted of five vertical slits through the side of the pressure pipe which extended across the filter box.

Piezometer connections to waterways under laterals when located midway between adjacent perforations, in order to avoid influence of jet velocity.

mains, connected with the complete filter layout as seen in figure 3. Throughout the experiments, 24 inches of filter sand were used,

leaving 24 inches of freeboard to the top edges of the box, which served as wash water gutter weirs.

Operating results of final experimental design

When washed, the sand presented a uniformly mottled appearance and was left, after each wash, smooth and level all over. An idea of the evenness of distribution may be gained by reference to figure 4. Uniformity of washing was accurately checked up by tapping with a sounding stick over each square inch of the gravel slab. With the slab finally "tuned up," no resistance due to the sand could be felt over the whole filter area, even at as low a rate of wash as 12 inches vertical rise per minute. Satisfactory distribution of the wash water at the 12-inch rate was taken as the rigorous criterion to which the operation of the distribution system must conform, since the effects of inequalities in the discharge of wash water over the filter area are far more pronounced at the low rates of wash than at the high rates, such as 24 inches, usually employed.

III. HYDRAULIC INVESTIGATIONS

Arrangement of apparatus and summary of hydraulic data

Having determined upon the design factors of the filter bottom that would surely result in a uniform distribution of the wash water, the hydraulic characteristics of the filter bottom were then investigated, as they appeared during washing. For this purpose, suitable piezometers, gage boards and appurtenances were installed as shown in diagrammatic outline in figure 5.

The over-all losses during washing were considered as comprising the following elements:

(*a*) The resistance of the perforated pipe laterals, including loss of head at entrance.
(*b*) The resistance of the cemented gravel slab.
(*c*) The resistance of the sand bed during washing.

Item (*a*), or the head lost through the perforated pipe laterals, can be readily calculated from experimental data already published and available to designers (2). The present series of tests demonstrated the possibility of using a combination of size and spacing of perforations that will result in a materially lowered loss of head.

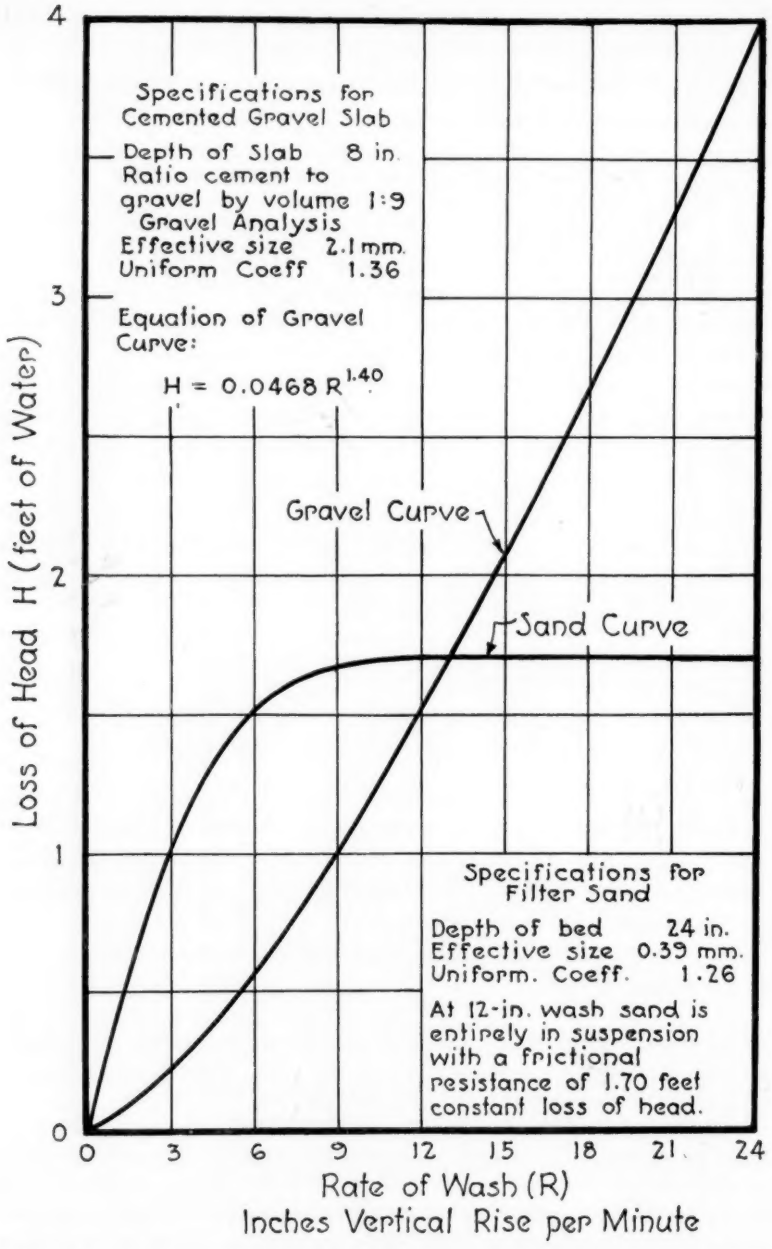


FIG. 6. DIAGRAM SHOWING LOSS OF HEAD THROUGH CEMENTED GRAVEL SLAB, AND THROUGH FILTER SAND, DURING WASHING

(From Test Data on Jenks Rapid Sand Filter Bottom)

without sacrificing uniformity of distribution. The frictional resistance of the cemented gravel slab admirably serves the purpose of maintaining the hydraulic equilibrium throughout the system.

In connection with item (*b*), or the resistance offered by the cemented gravel slab to the discharge of the wash water, the observed losses of head, as shown in the diagram of figure 6, fell within a range well above the critical resistances required for good distribution; yet the added loss of head can be more than offset by the decreased resistance permissible in the underdrain pipes, as noted in the foregoing paragraph. Hence the over-all, or total, loss of head through the new distribution system will, actually, rank intermediate between that of the usual perforated pipe underdrain system and the slat or wood grating bottom.

From a balanced curve drawn through the plotted points determined by the field tests, it was found that the relationship between the rate of wash and the loss of head through the cemented gravel slab as selected for the final design could be expressed by the equation

$$H = 0.0468\ R^{1.40}$$

where H = Loss of head, in feet of water; R = Rate of wash, inches vertical rise per minute.

For slabs of different depths, in inches (D), the general formula, $H = 0.00585\ DR^{1.40}$, may be used.

The foregoing relationships hold true only for slabs made according to the general specifications given in figure 6. It is believed that any gravel of substantially the same effective size and uniformity, and cast in a slab containing the same cement ratio, will discharge very closely the amount of water as computed by the formulas derived from the tests, for any assumed pressure head below the slab measured in the waterways underneath the laterals.

It is obviously impossible to predict the resistances that might be imposed through the use of cemented gravel slabs of other cement content or composed of different sizes of gravel. Such losses of head must be determined experimentally in each case. The necessary tests, however, can be made without difficulty, in connection with any proposed design (7).

In concluding this section, it will be of interest to state very briefly what was learned regarding the hydraulic conditions presented by

the sand bed during the washing of the filter. An analysis of the recorded observations indicate that the sand is not carried in full suspension until a critical rate of wash is reached. In the present instance, this rate was closely 12 inches vertical rise per minute. Furthermore, when the sand is entirely in suspension, the loss of head through the bed reaches a constant value, as may be seen by reference to figure 6. The piezometric heights, indicated in figure 5, also showed visually that the constant resistance eventually attained by the fully suspended sand is substantially proportional to the depth of the sand bed in place.

IV. DESIGN DATA AND NOTES ON CONSTRUCTION OF FULL SIZE FILTER BOTTOM

Installation in Filter No. 5 of the Sacramento plant

At the time the experimental development of the cemented gravel —vitrified clay pipe distribution system was completed, Filter No. 5 of the Sacramento plant had just been overhauled and was ready to have the filter bed replaced. An excellent opportunity was thus afforded of installing the new type of filter bottom in this unit. Since the experimental results were so satisfactory, it was concluded that the cost of construction on a full size scale would be fully justified, not only from the standpoint of completely demonstrating the value of the new underdrain system, but also of definitely assuring a substantial saving in cost of the additional filters that will soon become necessary to meet the increasing water consumption due to the rapid growth of the city of Sacramento. Accordingly, about the middle of October 1925, work was begun on rebuilding No. 5 filter bottom in conformity to the new design.

It will be of interest in this connection to note briefly the general features of Filter No. 5, which are typical of the entire group of filters. The filter unit is 58 feet in length by 31 feet in width. The filter bed is divided into two halves, each 12 feet in width, by a central drain trough and wash water manifold. With a net sand area of 1400 square feet, the filter has a capacity of 4 m.g.d. at the normal rate of filtration of 125 m.g.d. per acre. The elevation of the sand surface is such as to allow a depth of six feet of water to be carried on the sand bed. The original underdrain system comprised 12-foot perforated pipe laterals 3-inch size and spaced 12 inches apart. Perforations were $\frac{7}{16}$-inch in diameter, and spaced

6 inches on centers. The usual graded gravel bed, 22 inches in depth, completed the underdrain system.

Preliminary modifications to existing filter

As the distance from the top edges of the wash water gutters to the floor of the filter, as originally built, was approximately 75 inches, it was necessary to raise the floor of the filter to the level required by the considerably decreased total depth which the new filter bottom would occupy. This was done by pouring mass concrete over the floor after the original perforated pipe laterals had been removed. The new elevation to which the concrete was poured was determined by the following schedule:

	inches
Distance of sand below gutters	25
Depth of sand bed	24
Depth of gravel slab	8
Total	57

It should be noted at this point that this materially decreased total distance from the wash water gutters to the structural floor of the filter box is a further advantage in favor of the new type of filter bottom. For a given depth of water on the sand, a saving in excavation and material may be effected on the filter structure; while for a given elevation of the filter unit, an increased depth of water may be carried on the sand, allowing for that much more positive loss of head during the operation of the filter.

In order to connect, at the higher elevation, the new laterals with the main wash water channel, vitrified clay sewer pipe quarter bends, forming vertical offsets, were placed in the mass concrete and canted off to one side of the other of the cored holes, spaced 12 inches apart, so as to permit the sewer pipe laterals to be laid on 16-inch center lines. Although it would have been easier to use the original 12-inch spacing, it was determined to lay the new laterals 16 inches apart, as in the experimental filter, in order to demonstrate the possibility of a wider spacing of laterals in conjunction with the new filter bottom.

The surface of the mass concrete was left level but rough, for bonding with the cemented gravel slab. Smooth places resulting from screeding were roughened by raking. All laitance was removed, although only a few patches of laitance appeared.

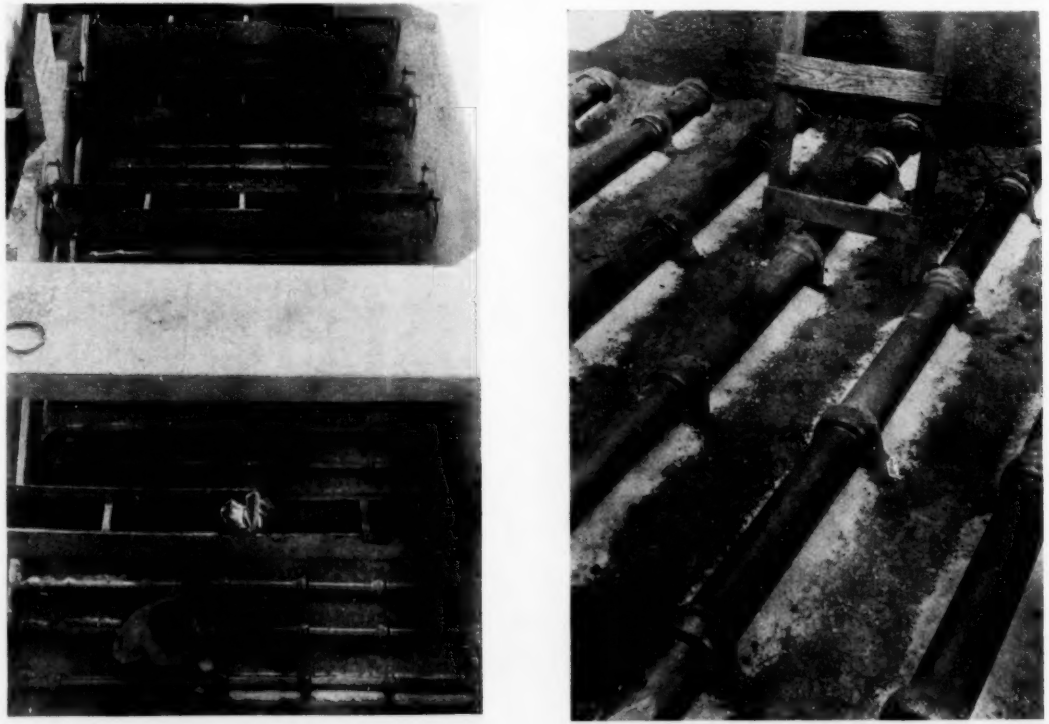
Installation of underdrain laterals

Manufacture of Perforated Sewer Pipe. The laterals consisted of standard 2-foot lengths of 3-inch sewer pipe, which was made in a local clay products factory. In connection with perforating the pipe, it was found possible to bore the holes in a drill press with a flat head drill, lubricated with water; yet it was thought advisable to have the perforations made before burning the pipe.

There is little difference in cost between the two methods of perforating the pipe. The decision would appear to rest chiefly on the judgment of the designer, as to which will produce the better perforations from the viewpoint of accuracy and durability. Drilled holes may perhaps be made more accurately, but on the other hand may not possess the resistance to the eroding effect of the high jet velocity of the issuing wash water, as holes punched through the pipe clay and subsequently glazed like the body of the pipe, when the clay is burned.

The manufacturer of the sewer pipe could not predict with certainty the amount of shrinkage to allow for when perforating the clay, but assumed a value of $\frac{1}{8}$ inch on a desired diameter of $\frac{1}{2}$ inch. When the pipe was burned it was found that this allowance was too liberal, the actual shrinkage amounting to slightly more than $\frac{1}{16}$ inch. The perforations accordingly averaged a full $\frac{1}{2}$ to $\frac{9}{16}$ inch diameter. The spacing of perforations of 6 inch was retained, as in the original underdrain system, making four holes in each length of sewer pipe between bell joints.

The holes were made in the pipe simply by punching them out with a wooden plug, the burr on the inside being swabbed out as the pipe was set aside to cure. The resulting orifices were circular in shape on the outside edge of the pipe, but the inside face of each hole was more or less ragged and somewhat cupped out from the interior surface of the pipe. While it was realized that on theoretical grounds such variations in the hydraulic conditions at each orifice would be objectionable, nevertheless it was decided at the time that the principle should be adhered to, that the new filter bottom must justify its use through satisfactory distribution of the wash water, in spite of any such irregularities in details of construction. It was considered logical to suppose that if such proved to be the case, there would be absolutely no doubt as to the satisfactory performance of the filter bottom as a distributing medium,



A *B*

FIG. 7. FULL SIZE INSTALLATION JENKS RAPID SAND FILTER BOTTOM

A. General view of west half of Filter No. 5 showing arrangement of underdrain laterals. Man in foreground placing salt under pipes to form waterways.

B. Detail of laterals indicating method of packing rock salt to form waterway for discharge of wash water from pipes. Note cement cutoff at each bell joint.

if built according to the usual rigorous specifications as to such matters as diameter of perforations in the underdrain laterals.

Placing laterals in filter

The laterals were laid in the filter 16 inches apart, on center lines, making a total of 88 laterals, or 44 in each half of the filter unit. The exceptionally wide spacing was chosen in order to prove the practicability of decreasing the number of laterals in the filter as a whole, thus reducing the cost of this item of the underdrain system. The laterals were installed in general agreement with the typical arrangement given in figure 1, and shown more particularly in the photograph of figure 7. The total number of perforations in each lateral was 23, all being a full $\frac{1}{2}$ inch in diameter, except a $\frac{3}{16}$-inch hole in each elbow projecting above the filter floor. The ratio of aggregate area of perforations to the area of filter sand bed was therefore equal to 0.226 per cent, or 0.327 square inch per square foot.

The installation of the laterals required 12 sacks of cement for the joints and the cement cutoffs at the bells, the mortar for this purpose being made of one part of cement and one of sand.

Construction of cemented gravel slab

The gravel used was obtained from a stock on hand of the pea gravel furnished for the top layer in the filter beds and subsequently removed when the filters were overhauled. The gravel was screened on a set of vibratory screens, in order to remove the filter sand with which it had become intermingled. This was accomplished by using a $2\frac{1}{2}$ mesh No. 20 wire, light hardware cloth in the upper screen holder of the apparatus, and a 14 mesh, No. 33 wire cloth on the lower holder. The product selected for the cemented gravel slab was that which passed the upper screen and was retained on the lower. A sieve analysis of this gravel showed it to have an effective size of 2.1 mm. and a uniformity coefficient of 1.36.

The cement and gravel were mixed in a standard paving mixer. Both materials were measured accurately by volume in buckets before placing in the receiving hopper. The mass was then mixed dry for 2 minutes, followed by a 3-minute mix after the addition of the water, which was measured in a bucket and poured into the mixing drum by hand. The proportions of cement, gravel and water were 1:9:0.5 by volume, respectively.

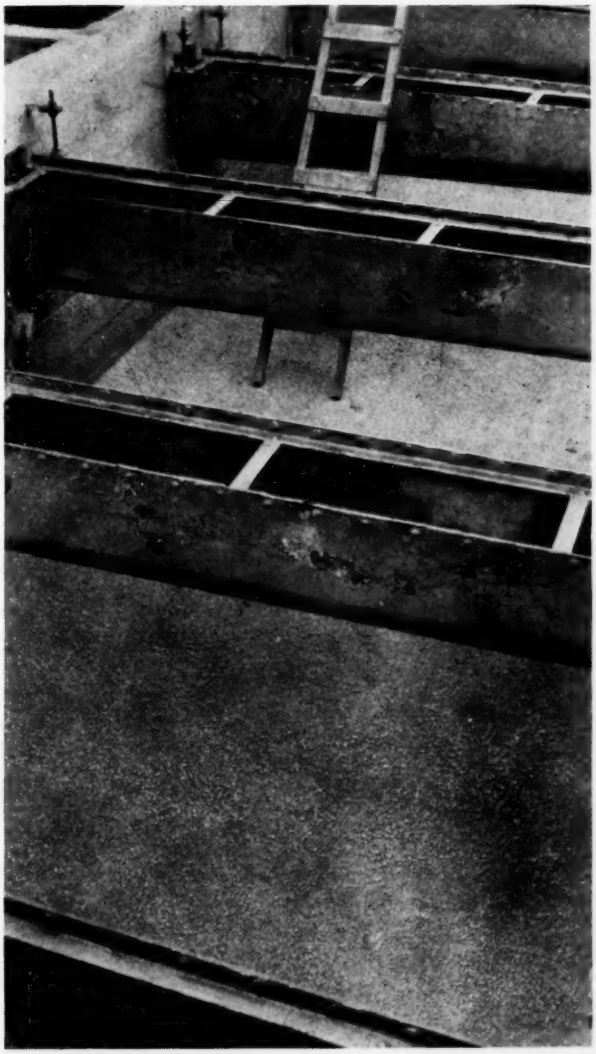


FIG. 8. CEMENTED GRAVEL SLAB IN FILTER NO. 5. OF THE SACRAMENTO PLANT

A portion of the slab completed. A uniform consistency was secured by thorough mixing. The slab was finished level by a screed suspended from adjacent wash water gutters, giving the surface a smooth, porous appearance.

As the slab was being poured, one man went ahead, placing the salt under the laterals to form the waterways. This is clearly seen in figure 7. When the first pour was made, the end of the working day came before one side of the filter was completed, so that a pour-joint was made by stopping the gravel to one side of a lateral. The following day the rest of that half filter unit was poured, a perfect bond being obtained with the old slab. It was found that, with a

TABLE 1

Cost of construction of Jenks rapid sand filter bottom, for one 4-m.g.d. filter unit

Underdrain laterals		
Perforated sewer pipe 1250 feet* @ 16¢	$200.00	
Incidental supplies	18.00	
Labor—21.6 man—days @ $5.50	118.80	$336.80
Cemented gravel slab		
Gravel—27.3 yards @ $3.38	$92.25	
Cement—86 sacks @ $0.75	64.50	
Salt—2400 pounds @ $7.15 per ton	8.60	
Labor—24.0 man—days @ $5.50	132.00	297.35
Total cost of construction		$634.15
Cost per square foot of filter area†		0.453
Comparative cost of perforated galvanized iron pipe underdrain system		
Assuming 116 laterals, 3-inch size, 12-inch spacing; and 20-inch depth of graded gravel above the laterals.		
Perforated pipe—1500 feet‡ @ 50¢	$750.00	
Gravel, screened—95 yards @ $6.00	570.00	
Labor—40 man—days @ $5.50	220.00	$1,540.00
Total cost of construction		$1,540.00
Cost per square foot of filter area		1.10

* Allows for wastage due to cut lengths.

† Area of filter equals 1400 square feet.

‡ Based on 13 feet over-all length of lateral.

gang of 12 men employed on this work, it was possible to pour the cemented gravel slab for the entire 4 m.g.d. filter unit in two working days.

The gravel as received from the mixer was perfectly uniform in appearance and no separation whatever occurred as it was wheeled to the point of discharge through suitable chutes onto the filter floor. When the gravel was spread over the bottom and worked into place.

no cement could be brought to the surface by tamping or troweling and no laitance appeared at any time. It was quite apparent throughout the entire job that the five-minute mixing was responsible for a most uniform consistency of the mass of cemented gravel, a fact that was later borne out by physical tests of this material.

The gravel was spaded around the laterals and walked on by the workmen, but no compacting of the material by tamping was resorted to. The slab was screeded smooth and level by a suitable screed suspended from the edges of adjacent wash water gutters, which had been previously set uniformly to the desired elevation. A finished surface of a uniformly porous appearance was produced, as shown in figure 8.

Due to the novelty of the design, the men displayed the greatest interest in making the work of construction as nearly perfect as possible. The pouring of the cemented gravel slab was finished during the second week of December 1925, and was allowed 28 days to set before being tested and placed in operation.

Construction costs

A statement of the amount and cost of supplies and labor for the complete cemented gravel slab—vitrified clay pipe distribution system, ready for operation, is given in table 1. The remarkable economy of installation of this type of filter bottom is strikingly evidenced by the unit cost of 45.3 cents per square foot of filter area, in comparison with a corresponding cost of $1.10 for a typical perforated pipe and graded gravel underdrain system.

Physical properties of cemented gravel

While the cemented gravel slab was being poured, representative samples were obtained for testing and record purposes. Specimens for tensile and compressive strength were tested after 28 days. The cemented gravel was found to have the following physical characteristics:

Weight per cubic foot	114 pounds
Ultimate strength	
Tension	78 pounds / sq. in.
Compression	403 pounds / sq. in.

The regularity of fracture that occurred upon failure indicated a homogeneous consistency of the material. The compression

specimens broke in well-defined cones, attributable to uniformity of strength throughout the section, and also to failure in diagonal tension. It was seen that this method of failure accounted for the relatively low ratio of compressive to tensile strength, as determined by the tests.

The average tensile strength of 78 pounds per square inch is to be regarded as very satisfactory, since, with a factor of safety of four, the safe allowable working stress for the cemented gravel becomes practically 20 pounds per square inch, equivalent to 46 feet of water pressure. As the loss of head through the cemented gravel slab of the filter bottom, as given in figure 6, is but 4.0 feet for a 24-inch rate of wash, the design described in this paper is more than sufficient for all operating requirements, from the standpoint of structural strength.

V. FILTER OPERATING DATA

Initial test of cemented gravel slab

After the slab had set for 28 days, the influent valve of Filter No. 5 was opened, allowing the filter to be filled to the height of the gutters. The water was then drained out of the filter through the drain plugs in the effluent pipe, the waste water being discharged into the floor drains of the pipe gallery.

The water in passing downward through the gravel slab, washed out the rock salt that had been used to form the waterways under the laterals. At first the water was noticeably salty to the taste, but after the water had drained down to the filter bottom, a laboratory test showed only the normal amount of chlorides in the water emerging from the filter, proving that all of the salt had been dissolved and carried out of the underdrain system.

The slab was then washed up to a 30-inch rate and thoroughly cleaned of all cement dust and loose particles. During washing, the water surface presented a smooth appearance, there being a remarkable freedom from any swirling or eddying due to inequalities in distribution. When drained, the filter bottom was found absolutely intact. The surface of the slab was hard and free from loose gravel, indicating an exceptionally good bonding of the material together.

Evidence pointed to a general absence of entrained air in the underdrain system. For one thing, the volume of voids in the 8-inch

gravel slab is much less than in the ordinary 18–22 inches of graded gravel; hence far less trouble should be experienced with air-trapping, in the case of the new type of filter bottom. This is of distinct advantage in diminishing the tendency towards shortened filter runs, due to air–binding.

Preliminary observations on wash water distribution

A 2-inch layer of filter sand was placed over the gravel slab and the filter was washed to determine the uniformity of distribution, preliminary to placing the full depth of sand bed in the filter. This procedure was followed in order to obviate the expense of the removal of a large volume of sand should the cemented gravel slab need to be corrected for uneven distribution in accordance with any of the methods devised during the testing of the experimental filter.

Washing was continued for 10 minutes, up to a 30-inch rate. There was a progressive and even clearing up of the water. The filter was then drained through the effluent pipe at the then existing rate of filtration (4.5 m.g.d. per filter), until the water level was within about two inches of the sand, after which the effluent valve was shut and the water level lowered slowly by draining through the waste water line. As the water level passed below the sand the water disappeared simultaneously from every square foot of the surface of the 2-inch layer of sand, which was found to be more nearly level, after having been washed, than it had been possible to screed it when placed in the filter.

Further proof of uniform washing was furnished by the fact that the surface of the whole sand bed presented an even, mottled appearance resulting from overlapping sand craters formed by the water issuing from the pores of the cemented gravel slab. Small patches of detritus and mud particles were themselves evenly distributed over the filter area.

As it was quite evident that the cemented gravel slab did not have to be modified in any way, the full depth of sand bed (24 inches) was then installed in the filter. When washed, the distribution of wash water was in every respect as excellent as it was before. All the observations led to the conclusion that the very promising results obtained in the experimental filter were even more fully realized in the full size unit.

After completing these preliminary tests, Filter No. 5 was placed in routine operation as one of the units of the Sacramento filtration

plant, for further testing and observation under actual conditions of service.

Results of routine operation

Filter No. 5, equipped with the cemented gravel slab—vitrified clay pipe distribution system, was placed in regular operation on January 16, 1926. Within a short time, the ordinary washing of the filter had brought all the fine sand and mud cakes to the surface, which was accordingly scraped off, leaving a sand bed depth of 24 inches above the slab, and a distance below the gutters of 25 inches.

As a routine procedure, the elevation of the sand in each filter is measured every week and the results entered on a chart which shows graphically any changes in sand depth from the original. Ever since the beginning, the sand records show that all disturbances of the sand bed have been entirely eliminated by the new type of filter bottom, the surface of the sand always remaining uniformly level and at the same elevation. No surging of the sand takes place, nor is any sand lost over the gutters due to inequalities in washing.

In comparison with the other filters of the plant, the condition of the sand is appreciably better. The obvious cleansing effect of each wash is most pronounced in the case of Filter No. 5, and the cumulative effect is reflected in a complete avoidance of sand bed cracking around the edges of the filter.

The results of operation over a period of time point to the fact that, as a distribution system for the wash water, the new filter bottom may be regarded as eminently satisfactory. In every particular it is at least the equal of the conventional perforated pipe under drain system, under all operating conditions encountered at the Sacramento plant; and at the same time it possesses features of merit not found to the same degree in any other type of design.

The very nature of the new distribution system makes it as nearly fool-proof as it is perhaps possible to construct it. For this reason, the filter operators are very partial to the new design, as they are confident that nothing can disrupt the filter bed during washing; and the condition of the sand is under full control in so far as it is the function of washing to maintain it in proper order.

An examination of the physical state of the cemented gravel slab after three months' operation showed that it was structurally intact.

When tapped on the surface with a square point shovel, a ringing sound was given out, characteristic of well knit, homogeneous concrete. The only noticeable change in the condition of the slab was a slight amount of raveling of the cemented gravel at the surface. If, in the course of time, such raveling continues, it is believed that it can be effectively checked by interposing an inch or two or loose pea gravel between the cemented gravel slab and the overlying sand.

It is pertinent to the subject to consider at this point the general question of the continued stability of the cemented gravel slab. It is realized that as a matter of fact, nothing but the test of time can demonstrate the ultimate durability of this material, particularly where the type of water filtered may have a chemical influence on its permanency. It is the opinion in some quarters that porous gravel tends to become more porous as time goes on; then again, some claim that it will eventually become clogged. If the view is held that the gravel will disintegrate, then it would appear that for the design to be of practical value, the slab should have a useful life of perhaps 10 years. After such a length of time, a new slab could readily be installed, charging its cost against depreciation. In contrast to disintegration, if the slab showed a tendency to clog, it would probably be due to the same causes responsible for the growth of sand in the filter bed. The same remedial measures designed to relieve the coating of the sand grains would also presumably arrest the clogging of the cemented gravel slab. These same considerations would doubtless apply in the case of porous mediums other than cemented gravel that might be employed as part of the filter bottom under discussion, in case the ordinary portland cemented gravel slab should prove to be unsatisfactory as to durability.

It is suggested that cements of high alumina content or else a porous asphalt paving mixture may be substituted for ordinary portland cemented gravel, if necessary. These are matters of conjecture until the completion of the present experimental full scale tests at the Sacramento filtration plant.

In contrast to these uncertainties there stands the fact of the mechanical strength and resistance to erosion possessed by the cemented gravel. On account of these properties, its use as a distributing medium in a rapid sand filter is, in the opinion of the speaker, fully justified, especially when the accompanying economy of installation and the superior advantages of operation are also taken into con-

sideration. Based on this view of the matter, the decision has been reached to embody the new design in the 8 additional 4-m.g.d. filters proposed for the Sacramento plant for the year 1927, provided the problem of durability can be successfully met. In addition to a substantial saving in cost of construction, the cemented gravel slab—vitrified clay pipe distribution system would insure the numerous improvements in operation already demonstrated by actual experience.

VI. ACKNOWLEDGEMENTS AND BIBLIOGRAPHY

Throughout the many weeks of experimental work and the subsequent construction of the full size installation of the new wash water distribution system, helpful coöperation was given by members of the operating staff of the filtration plant. Particular mention should be made of the painstaking and excellent work done by the filter attendants, Joseph Callahan, George Mansfield, and Fred Cornelison, upon whom chiefly devolved the work of constructing the experimental filter apparatus and of rebuilding the underdrain system of Filter No. 5 according to the new design. In making the many observations and tests during the course of the experiments, Carl M. Hoskinson, Chief Engineer, and Ralph A. Stevenson, Chemist and Bacteriologist, rendered very helpful assistance. The speaker also wishes to acknowledge the kindness of Allan J. Wagner, City Engineer, in facilitating the completion of the experimental work and in authorizing the full size filter installation.

In conclusion, and in relation to the work described in this paper, the speaker has the happy privilege of recording here his deep appreciation of Charles Gilman Hyde, designer of the Sacramento pumping and filtration works, and Professor of Sanitary Engineering University of California, whose instruction, personal friendship, and high professional attainment, have in large measure inspired and sustained the ambition of the speaker to contribute to the advancement of the art and practice of the purification of water by rapid sand filtration.

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(7) BEYER, MASON AND NICKEL 1925 Thesis in College of Civil Engineering University of California. A study of porous cemented gravels to determine hydraulic resistances and behavior as air diffusers.

DISCUSSION

HARRY N. JENKS[1] (by letter July 27, 1926): Since presenting his paper on the cemented gravel—vitrified clay pipe distribution system developed at the Sacramento filtration plant, the writer, in numerous conversations with engineers and plant operators, has been impressed with the fact that the question uppermost in their minds was that which concerns the ultimate durability of the cemented gravel slab. The uncertainty of this feature of the new design was recognized by the writer throughout the various stages of the work, and he took the opportunity of emphasizing this matter in the closing section of his paper. That this caution in predicting the outcome of the full size test then under way was well founded, became clear when, after six months' operation, the cemented gravel slab was found to have disintegrated seriously under the chemical influence of the water being filtered.

Were it not for the fact that in every other respect the new design had fully established its claim for recognition as a desirable filter bottom from the standpoint of cheapness of cost and certainty of satisfactory filter operation, the subject matter of the writer's paper might have become of little practical consequence. However, because the design still appeared fundamentally sound, there was every reason for continuing the work of developing a new cemented gravel slab that should possess the needed characteristic of durability.

During several weeks in June and July (1926) the writer proceeded with research work along this line, experimenting first with a high alumina cement. Then upon the suggestion of Charles G. Hyde, he discarded, for the time being at least, all other cementing materials in favor of asphalt cement. Test specimens were made in the laboratory of the filtration plant which contained asphalt ce-

ment and various proportions and grading of gravel and crushed rock. After many trial combinations, it was determined that an asphalt cemented gravel possessing the required characteristics could be made, using crushed rock and "Petrolastic" asphalt, according to the following formula:

MATERIAL	PASSING SCREEN	RETAINED ON SCREEN	PER CENT BY WEIGHT
Crushed rock	½"	¼"	50
Crushed rock	¼"	No. 10	35
Asphalt			15
			100

In arriving at the selection of this mix, the writer followed many helpful suggestions made by Charles S. Pope, Chief Construction Engineer, California Highway Commission, whose valuable advice was sought in this connection.

The rock used was standard crusher run, supplied by local contractors for asphalt paving work. The "Petrolastic" asphalt is a high-grade asphalt prepared by the Standard Oil Company of California. It possesses a relatively high melting point (180°–232°F.), and high ductility and hardness when cold. Specimens of the asphalt cemented gravel under hydraulic test showed the same general characteristics as the cemented gravel described in the writer's paper. The physical features are also quite similar, except that the tensile strength of the asphalt mix is lower than that for the portland cemented product. The weight per cubic foot was found to be some 10 per cent greater, or approximately 125 pounds.

At the time of writing, complete test data on the material itself are not yet available. Also, it is still too early to report on the success attained with its use in the full size filter installation. This work should be completed by the end of August of this year (1926), and the writer anticipates being able to furnish at a later date detailed information of general interest in this connection.

The work of construction with the improved type of cemented gravel slab is essentially the same as with the original slab, except that the material is poured hot, and is purposely compacted thoroughly to obtain the maximum possible density consistent with the required porosity. One construction advantage of asphalt cemented gravel is that the slab is ready for use within 48 hours after pouring.

The cost of the filter bottom will be increased slightly by the difference in price of the asphalt and portland cement. At Sacramento, the asphalt costs $35.00 per ton delivered. Figures are not yet available showing the comparison between the labor costs of installation, but there should not be a material difference, at least in localities where asphalt plants can furnish this material ready mixed and hot, for placing in the filter box.

Referring again to the failure of the original cemented gravel slab, the writer is not fully convinced that ordinary cemented gravel is unsuited to all waters. It appears to him that in hard waters, where the tendency would be for salts to be deposited in the interstices of the sand bed and gravel slab, a protective coating would be secured, that would lengthen the life of the slab to a satisfactory extent. The subject should be a fruitful one for discussion on the part of the chemist as well as the engineer in our water works field.

As a possible aid to a discussion of this matter from the chemical point of view, the following table is submitted to show the significant chemical characteristics of the water passing through Filter No. 5 of the Sacramento plant, for the first six months of 1926:

	ALKALINITY	FREE CO_2	DISSOLVED OXYGEN
	p.p.m.	*p.p.m.*	*p.p.m.*
January	61	10	12
February	27	15	12
March	35	9	12
April	23	6	12
May	27	8	10
June	59	9	

The disintegration of the cemented gravel slab constructed as described in his paper gave the writer the impression that the case was analogous to corrosion of any other surface in contact with water, such as a pipe line. It has been determined that a fairly definite relationship exists between hot water service corrosion in the Sacramento distribution system and the carbon dioxide content of the water, under conditions of alkalinity and dissolved oxygen associated with the free carbon dioxide at the time. This point is closely 10 p.p.m. of CO_2. It would be interesting to know whether a similar critical point of "corrosion" for the cemented gravel could be established. If such proved to be the case, the limitations of

portland cemented gravel could be ascertained with fair definiteness and in instances where the "corrosion" of the slab is to be feared, asphalt cemented gravel could be employed, or some other porous medium that may later be devised.

CHARLES GILMAN HYDE:[3] It is an unusual pleasure and privilege to discuss a paper which has been so carefully and capably prepared and which presents in clear, authoritative, comprehensive, and interesting fashion a distinctly new idea and procedure in the design and construction of underdrainage systems for rapid sand filters. The writer does not hesitate to proclaim his belief that the author has made the most significant contribution to the development of this fundamentally important feature of rapid sand filters which has been made since the Harrisburg type of underdrain was first designed by the writer in 1902 to carry out the novel and quite original idea of James H. Fuertes.

The Harrisburg type of underdrain greatly simplified the rapid sand filter and proved to be equally effective for both air and water washing. Mr. Jenks' design carries the simplification of the filter bottom still further and provides for both air and water washing in a still more positive way. This new filter bottom eliminates two relatively expensive items, namely, perforated pipes of metal and a considerable depth of gravel, sized or graded with great care and placed in several well defined layers or courses. Cheap, non-corrodible, perforated vitrified clay pipe replaces the steel or brass pipes heretofore employed. The single layer or slab of cemented gravel replaces the several courses of gravel of much greater aggregate depth. It positively eliminates all possibility of gravel disturbance especially the disturbance of the finer top courses upon which the very integrity of the main body of filter sand depends. With all other designs utilizing uncemented gravel layers there is the inevitable risk of displacement due to sudden high rates of air or water washing or to the sudden release of entrained air. The deeper and coarser the gravel the greater may be the volume of entrained air.

The author has frankly called attention to the fact that the life of the cemented gravel slab is still in doubt. Experience alone can demonstrate its durability under differing conditions and charac-

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teristics of the water undergoing treatment. There does not seem to be any acceleration test by which its durability under various conditions can be truly forecasted. If there should be a tendency to deposit normal carbonates it is evident that the life of the slab would be dependent not upon the rate of disintegration but upon the rate of pore filling. If iron or manganese should be deposited therein the same problem of interstitial clogging would obtain.

In that general connection two points are to be noted: (1) the cemented slab can be quickly removed at low cost by the use of pneumatic chisels; (2) the expense of replacement would be so small that even a few years of life would justify its use as compared with other types. Consider, for instance, a perforated galvanized iron pipe system and the usual deep body of gravel. Taking the figures given by the author as representing the costs at Sacramento, namely, $0.45 per square foot for the Jenks filter bottom and $1.10 for the Harrisburg type of underdrain, and assuming a life of 25 years for the latter, this question may be asked "Based upon construction costs alone and neglecting the value of the time lost in the use of a filter having the new type of bottom during its reconstruction, what period of years of actual life would place the two types of filter bottom upon an equivalent economic basis?" With interest taken at five per cent per annum, depreciation figured on a straight-line basis, and neglecting any salvage value of the vitrified clay pipes, it would appear that the new type of bottom could be replaced every 10 years and yet be on the same economic basis as the older type lasting 25 years. If the vitrified clay pipes could be completely salvaged, which seems to be quite possible, the Jenks bottom could be replaced every eight or nine years and yet be on the same economic basis as the Harrisburg type lasting twenty-five years. The time required for the hardening of the cemented slab might be appreciably decreased by the use of "Lumnite" cement or other high aluminum cement, although the durability of this material under the imposed conditions is perhaps open to question. Doubtless other cementing materials may be found or may be developed in the future. That portland cement itself will be gradually improved in strength and durability under the stated conditions may also be anticipated.

Several engineers, notably James W. Armstrong at Baltimore, have successfully used very inexpensive slat bottoms of wood supporting the usual deep gravel body in several courses. Such bot-

toms cannot be employed for air washing, but may be employed for water washing at all desirable rates. The partial failure of the north tier of four filters at Sacramento, equipped with such bottoms, must be attributed in part to surging in the main central wash-water channel. The writer has successfully employed this type for the purification of sea water in seven small filters having a total capacity of one million gallons per 24 hours at the Crystal Palace Salt Water Baths in San Francisco. In this case the velocity of the wash water is reduced to comparatively low terms as it enters the equalizing chambers beneath the slat bottoms. Notwithstanding this precaution, it appears that some surging in these chambers does occur. This is indicated by the swirling of the water above the sand. At the best, slat bottoms are extremely sensitive because they offer virtually no resistance to the passage of water through them and it is evident that there must be no appreciable recovery of velocity head within the equalizing chambers beneath. The use of slat bottoms can be made more positively reliable if cemented slabs are employed above them rather than the usual gravel layers. This was not done in the case of the Crystal Palace Salt Water Baths because it was felt that such slabs would not be durable in salt water.

A similar group of filters is being constructed under the writer's design for the new Hearst Memorial Hall for Women at the University of California. The supply to these filters will be fresh water. It is therefore proposed to employ a slat bottom surmounted by a cemented gravel slab 4 inches in thickness of composition similar to that employed at Sacramento and also similar to the experimental slabs first made by the writer two years ago. Had Mr. Jenks' idea been available when these filters were being designed, the writer would have been glad to have employed it. The Jenks filter bottom will undoubtedly find a very wide sphere of usefulness and will make possible large savings in cost of construction of rapid sand filters and perhaps, also, of slow sand filters.

A. C. BEYER:[4] The following discussion contains the summary of the methods followed and results ob...ed by J. L. Mason, H. G. Nickle, and the writer in their work on a Thesis, referred to by the author and entitled "An investigation of the use of porous concrete mixtures as filter underdrains and as air diffusers." This work was

[4] San Francisco, Calif.

carried out in the Civil Engineering Test Laboratories at the University of California at the suggestion and under the supervision of Professor Charles Gilman Hyde.

In brief the laboratory work was as follows:

1. Rating of sand sieves, a gas meter and a standard triangular weir.

2. Preparing the test blocks and compression cylinders from different effective sizes of aggregate and different proportions of concrete.

3. Tests of specimens. These were three-fold in nature.

The first consisted in measuring the loss of head for different rates of flow of water through the test blocks of porous concrete. The second had to do with the rate of flow and the degree of diffusion of air, under varying pressures, through the test blocks made from the smaller effective sizes of aggregate. The third were compression tests of standard 2-inch by 6-inch cylinders.

The sieves were of a standard make with square openings. Each was rated by calculating the size of particles just passing through its openings. This method involved counting the number of grains of sand, determining specific gravity by the pyknometer, and then calculating the grain diameter on the assumption that the grains so counted were all spherical and equal in size. This method of rating was further checked by direct measurement of the size of opening, using a micrometer comparator.

The first step in making the test blocks was to screen the gravel and sand, as received, through a series of nine sieves. This series included eight sieves rated as described above—a $\frac{1}{4}$ inch and No. 4, 6, 10, 16, 20, 24 and 30—having openings as listed in the accompanying table in the column of effective size of aggregate. The other sieve, used as a preliminary or roughing screen, had openings of approximately $\frac{3}{8}$ inch or 9.5 mm.

To get an aggregate of a particular effective size the material retained on the screen with that size of openings was mixed with the material retained on the next smaller sieve, in the ratio of 9:1. This resulted in aggregates which were quite uniform in size, with a uniformity coefficient of probably less than 1.5.

Twenty-four blocks 8 by 9 by 4 inches were made. The proportion of cement and effective size of aggregate for each block is given in table 2. Only enough mixing water to give normal consistency was used. After forty-eight hours the blocks were removed from the mold and cured in water for twenty-eight days. Figure 9 shows the texture of the blocks made from the larger sizes of aggregate.

TABLE 2

Experimental data and results

BLOCK NUMBER	EFFECTIVE SIZE OF AGGREGATE	CEMENT RATIO (BY WEIGHT)	DENSITY	COMPRESSIVE STRENGTH AT 28 days	WATER TESTS—LOSS OF HEAD (FEET OF WATER) FOR VARYING RATES OF FLOW									AIR TESTS—DISCHARGE OF AIR THROUGH BLOCK IN CUBIC FEET PER SQUARE FOOT PER MINUTE*			
					Rate of flow (inches of vertical rise per minute)									Pressure drop in pounds per square inch			
					12	15	18	21	24	27	30	36	42	1.5	2.5	3.5	4.5
	mm.		*pounds per cubic foot*	*pounds per square inch*													
17	6.35	1:6	114	283	0.036	0.045	0.056	0.069	0.084	0.101	0.119	0.156	0.198				
20	6.35	1:9	112	310	0.026	0.034	0.044	0.054	0.065	0.076	0.088	0.177	0.152				
21	6.35	1:12	109	138	0.017	0.021	0.026	0.032	0.038	0.044	0.052	0.067	0.085				
2	5.48	1:6	116	329	0.038	0.046	0.061	0.075	0.091	0.108	0.127	0.175					
1	5.48	1:9	112	224	0.034	0.040	0.044	0.057	0.071	0.087	0.104	0.141	0.182				
5	5.48	1:12	110	94	0.030												
3	3.52	1:6	110	340	0.066	0.086	0.112	0.142	0.176	0.211	0.250	0.331					
4	3.52	1:9	106	198	0.034	0.040	0.050	0.061	0.073	0.086	0.100	0.132	0.173				
6	3.52	1:12	110	123													
7	2.00	1:6	110	517	0.090	0.112	0.138	0.166	0.199	0.237	0.280	0.386					
8	2.00	1:9	108	314	0.086	0.105	0.132	0.158	0.186	0.220	0.260	0.354	0.455				
9	2.00	1:12	107	138	0.080	0.100	0.125	0.151	0.178	0.210	0.247	0.336	0.445				

10	1.14	1:6	113	269	0.37	0.47	0.54	0.65	0.76	0.90	1.07			13.0	18.0	21.6	24.3
11	1.14	1:9	107	177	0.26	0.32	0.39	0.47	0.56	0.65	0.74	0.96					
12	1.14	1:12	104	106	0.20	0.25	0.30	0.37	0.44	0.52	0.60	0.79		12.5	17.5	21.0	23.4
13	0.91	1:6	109	311	0.90	1.1	1.35	1.66	2.04	2.45	2.90	3.83	4.9	9.4	14.1	18.5	23.0
14	0.91	1:9	104	140	0.90	1.1	1.28	1.55	1.86	2.26	2.68	3.66	4.9	12.0	16.5	20.5	24.0
22	0.91	1:12	108	236	0.90	1.1	1.40	1.75	2.20	2.68	3.18	4.30		12.6	16.9	21.0	24.3
23	0.712	1:6	113	89	10.6	13.0	15.2	17.0						5.6	9.5	13.3	17.1
15	0.712	1:9	105	149	6.1	7.6	9.3	10.8	12.4	13.8	15.3	18.5		9.7	14.4	18.3	21.5
18	0.712	1:12	102	85	4.1	5.2	6.2	7.3	8.4	9.4	10.4	13.3		11.6	16.5	20.4	23.5
24	0.492	1:6	109	325	11.1	13.1	15.2	17.3	19.2	21.2	22.9	26.2	29.2	4.5	9.5	13.7	17.3
16	0.492	1:9	105	164	6.9	8.6	10.3	12.0	13.6	15.2	16.6	19.3		6.9	14.0	18.9	22.2
19	0.492	1:12	101	94	4.1	5.5	7.0	8.3	9.6	10.8	12.1	14.5		8.4	14.9	19.4	22.6
Filtros, grade "R," 1½ inch thick														10.0	15.3	19.5	22.9

* Influent air at 60°F.; effluent air at atmospheric pressure = 14.7 pounds per square inch.

The compressive strength tabulated is the average of tests of three A. S. T. M. Standard 2 by 6-inch cylinders for each one of the twenty-four mixes.

Both the water and air tests were carried out in the same test box. In testing, a block was caulked tightly in a box, just enough larger in plan than the 8 by 9 inch dimensions of the blocks to enable a specimen to rest on a ledge 3 inches above the bottom of the box. Thus the results are for a slab thickness of 4 inches. Figure 10 shows the details of the testing box.

In the water tests the water entered below the block, passed up through it and out over the standard triangular weir at the top.

FIG. 9. TEST BLOCKS USED FOR AIR DIFFUSION EXPERIMENTS

The usual formula for that type of a weir was used in calculating flow rates. The accuracy of the calculated rates was checked by calibration, the discharge for different time intervals being weighed. The difference in head between the bottom and top of the block—i.e., the loss of head through it—was gotten by piezometer connections. For measuring the higher head differences the water column was replaced by a mercury manometer. Figure 11 gives a set of curves plotted from the tests on the group of blocks made from the aggregate of effective size of 6.35 mm.

The air tests were similar to the water tests except that for a given pressure the quantity of air was measured by use of an ordinary gas

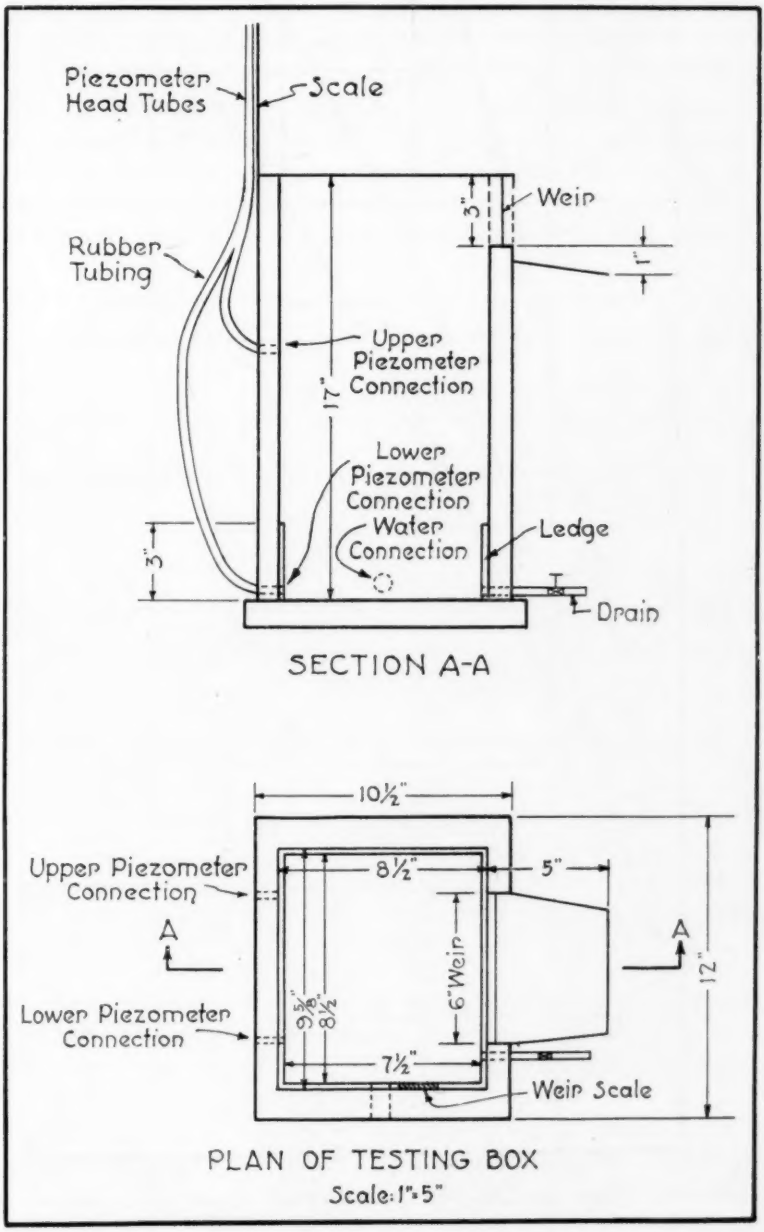

FIG. 10. DETAILS OF TESTING BOX

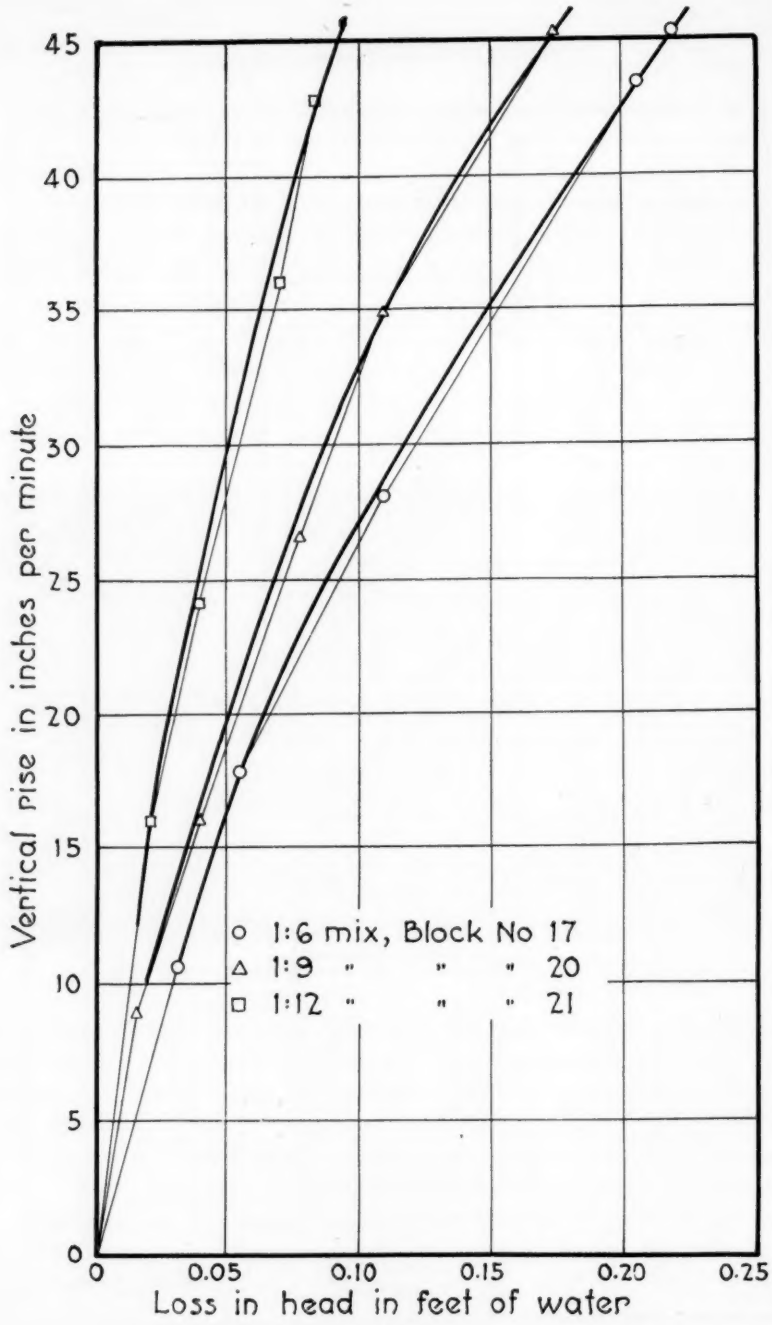

FIG. 11. FLOW OF WATER VS. LOSS OF HEAD

Curves showing relation between rate of flow in inches of vertical rise per minute and the loss in head in feet for an effective size = 6.35 mm. and for various mixes.

meter such as is employed by gas companies in domestic service. The meter was calibrated, using a standard orifice which in turn had been rated, as well as designed and built, by Prof. R. S. Weeks, Mining, University of California. The pressure was recorded by a Bourdon type gauge on the air line. The accuracy of the gauge was checked by a mercury manometer at the same time the gas meter was tested.

Several inches of water were placed over the top of each block when

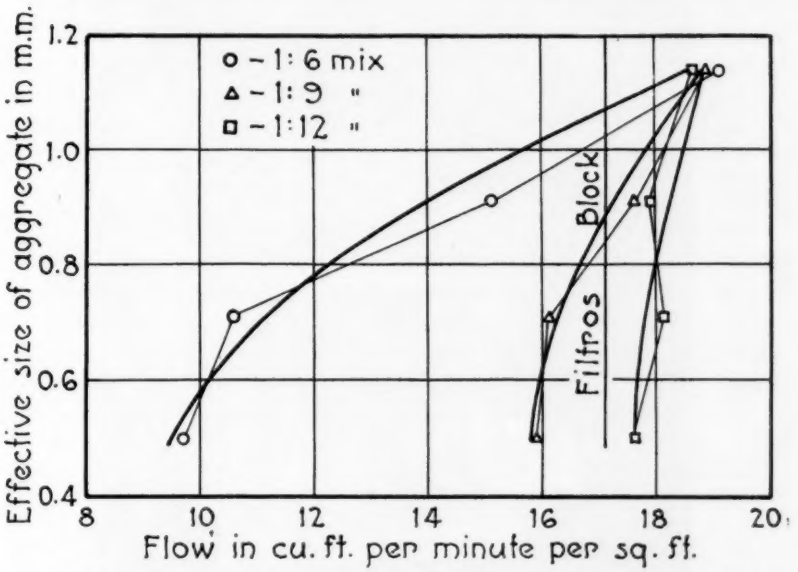

FIG. 12. RELATION BETWEEN FLOW OF FREE AIR AND EFFECTIVE SIZE OF AGGREGATE OF BLOCKS FOR A PRESSURE OF 2.8 POUNDS PER SQUARE INCH AND FOR VARIOUS MIXES AND A COMPARISON WITH THE FLOW THROUGH FILTROS BLOCKS WITH SAME PRESSURE

testing in order that the degree of diffusion of the air could be noted. For the blocks tested the degree of diffusion observed compared favorably with that got from a Filtros block. Figure 12 gives a graphical summary of certain of the air tests.

The Filtros block referred to was an 8- by 9-inch specimen cut from a grade "R" slab $1\frac{1}{2}$ inches thick as supplied by the General Filtration Company, Rochester, New York. Filtros blocks of this grade are quite generally used for air diffusion in the activated sludge process of sewage disposal. The object of the test of this material was to give

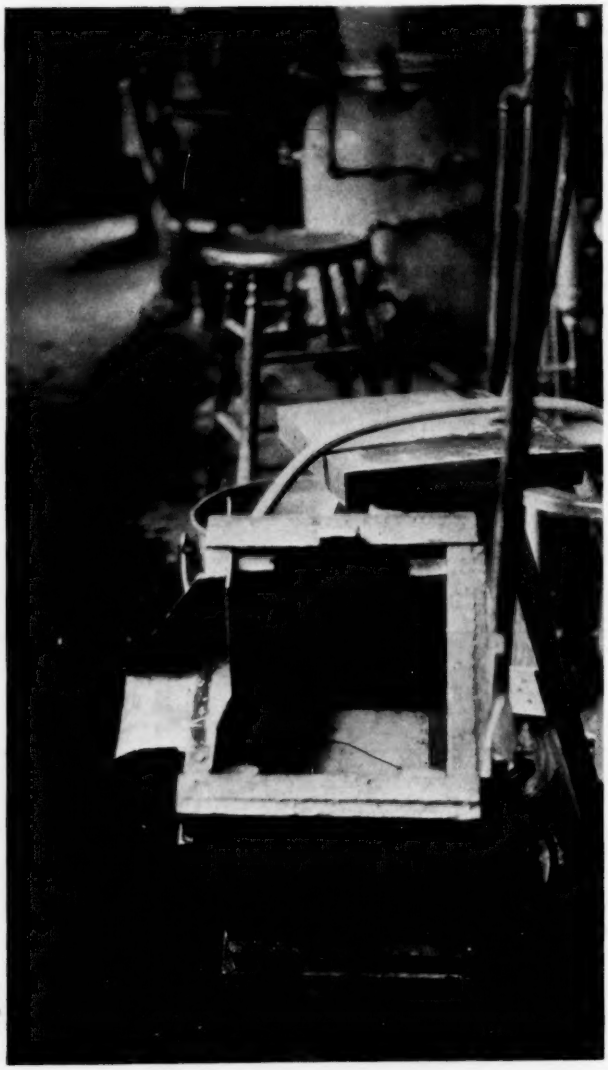

FIG. 13. FILTROS BLOCK READY FOR TESTING

a fairly standard basis for the comparison of results. Figure 13 shows the Filtros block caulked in place ready for testing and also gives some idea of the details of the test box.

Table 2 contains a summary of the results obtained by the writer

and associates. The values given for the water and for the air tests were taken from curves plotted from experimental results. A set of such curves is shown in figure 11 referred to above.

The ordinary unit—inches of vertical rise per minute—used for measuring filter wash water rates is the basis for presenting the loss of head data for the water tests. It is to be noted that the data of the air tests differ from those of the water tests, the rate of flow being tabulated in the former case and the loss of head in the latter.

In spite of the fact that the results presented were obtained from either single specimens or from a limited number of specimens the writer feels that these figures are reliable as an indication of what may be expected from the same or similar blocks or slabs. He points to the consistency of the results, taken as a whole, as sufficient reason for his opinion in this regard.

At the time, the men who carried out the Thesis were very much impressed with the possibilities presented by the data secured, especially in the case of the water tests. However, Mr. Jenks' work in developing on a practical basis the design and construction of his type of under-drainage system is most ingenious and even surpasses the future progress hazily pictured by the writer during the enthusiasm arising from what he considered was the successful outcome of his experimental work.

THE ECONOMICAL CAPACITY OF FILTERS AND FILTERED WATER STORAGE

By Arthur B. Morrill[1]

INTRODUCTION

In the design of water filtration plants it has been general practice to provide a certain amount of filtered water storage. In this way, during peak hours, it has been possible to deliver water to the distribution system at a higher rate than that at which it was produced by the filters, the excess coming from the storage reservoir. Thus the peaks and valleys of the consumption curve are somewhat smoothed out by the storage, so that the demand on the filter plant is more uniform than the demand on the distribution system.

But the demand on the filter plant, though it may be uniform for a day or more, is never made uniform throughout the year. This would permit a smaller filter plant, but would require an unreasonable amount of filtered water storage. The non-uniformity of demand is thus borne in part by the filtered water reservoir and in part by having a filter capacity in excess of the annual average demand.

The distribution of this burden between the filters and the filtered water storage is a question which deserves more careful study than it generally receives. That it is capable of exact analysis is shown in Chapter XIV of the American Water Works Association Manual, "Water Works Practice." When the Manual appeared a study was already under way at Detroit to determine whether the storage available at the existing filter plant should be increased, and also to determine the proper relation of filter capacity and filtered water storage for a new filtration plant to be built in the near future. The methods used in the Manual were found to be of great assistance, and the Detroit study thereafter proceeded along the same lines. The following is a summary of the method of analysis and of the results obtained.

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MOVING ANNUAL AVERAGE PUMPAGE

In previous studies the capacity of the proposed new reservoir for the existing plant at Water Works Park had been considered as a percentage of the maximum day pumpage. In the present study all computations were referred to the annual average pumpage. This is the basis used in the discussion in the "Manual of Water Works Practice" and in general appears to be a better basis of comparison.

To obtain true results, some attention must be given to the method of obtaining this annual average pumpage to which other capacities are referred. Due to the natural growth of Detroit, the normal rate of pumpage is continually increasing, so that the annual average for the calendar year, or for the fiscal year ending June 30, is not a proper basis of reference unless the hourly or daily pumpage under consideration occurs near the middle of the year in question. The average pumpage for any fiscal year may be considered to represent the normal pumpage as of January 1 of that year, as that day is at the center of the period under consideration. If a maximum or minimum day or hour happens to occur on or near January 1, the ratio of that quantity to the average for the fiscal year represents accurately the variation of that quantity from the normal. If, however, a maximum day or hour occurs in June and is referred to the annual average for the current fiscal year then just closing, it is referred to a value somewhat less than the true normal at that time, and consequently the ratio obtained is greater than it should be. Similarly, if a maximum day or hour occurs in July and is referred to the annual average for the fiscal year just then beginning, it is referred to a quantity larger than the true normal at that time, and so the ratio obtained is somewhat smaller than it should be.

In the present study this difficulty was overcome by calculating for each month for several years past the "Moving Annual Average." To do this, the pumpage of the particular month was added to the pumpage for five and one half months before, and five and one half months after that month. This then gave the total pumpage for that year of which the particular month was the center. This quantity divided by 365 was considered to be the moving annual average pumpage in million gallons per day for that month. Similarly a moving annual average for any day could be calculated, but as the increase from month to month is only about one million

gallons per day, or about one-half of one per cent, the moving annual average pumpage for the month was used in studying any maximum or minimum which occurred on any day during that month.

CRITICAL PERIODS STUDIED

The information readily available regarding high rates of pumpage in Detroit included only the maximum day and the maximum hour in each fiscal year. For the present work it would have been desirable to know the maximum two days, the maximum three days, etc., the maximum week, the maximum two weeks, etc., for each fiscal year. It will usually happen that the maximum week of any fiscal year includes the maximum day, but this does not necessarily follow. To locate absolutely the maximum periods of various lengths in each fiscal year, would have required an amount of labor which did not appear to be justified by the circumstances.

This study was accordingly limited to the three weeks period including the maximum day, for each of the five years ending June 30, 1925. The hourly pumpages for each such period were obtained, starting with the second Sunday preceding the maximum day and ending with the second Sunday following the maximum day. There was also studied a similar three weeks period in February 1918, when the maximum day ratio reached 1.45, a value which it has not exceeded since, and which was not exceeded previously for a number of years.

From the above, it is apparent that the study of the data was not sufficiently detailed to insure that the most extreme periods were located absolutely. It was believed, however, that the periods studied were the most critical in the last ten or fifteen years, and so that the results obtained were reliable, although some allowance doubtless should be made for the fact that the absolute maximum in the period studied may not have been found, and that the maximum in the immediate future might be greater than the recorded maximum in the past.

DIAGRAM OF FILTER AND RESERVOIR RATIOS

The size of filtered water reservoir required for any given filter capacity, based on Detroit's experience, is shown in figure 1. The capacity shown is that required for equalizing purposes alone. Whatever additional storage is required for fire protection, or as a

safeguard in case of accident, must be determined in some other way and that amount added to the amount shown on the diagram to obtain the total reservoir capacity to be supplied.

In previous discussions the reservoir capacity had been considered to depend upon the length of time over which the pumpage was to be equalized. To equalize the flow on a maximum day in the summer, however, would require as much as 18 per cent of the flow of an annual average day, while to equalize a maximum day in winter may require only 4 or 5 per cent of an annual average day's pumpage. The winter day may be more extreme as far as total pumpage is concerned than the summer day, but on account of excessive pumpage at night, the distribution is much more uniform and so the

TABLE 1

Relation of filtered water storage to filter capacity

FILTER CAPACITY IN TERMS OF ANNUAL AVERAGE PUMPAGE	REQUIRED EQUALIZING STORAGE IN TERMS OF ANNUAL AVERAGE DAILY PUMPAGE
1.00	12.8
1.10	3.5
1.20	0.98
1.30	0.26
1.35	0.14
1.40	0.105
1.50	0.050
1.60	0.016
1.70	0.0046
1.79	0.0000

capacity required for equalization is correspondingly low. Thus there is no consistent relation between the required size of reservoir and the length of time of equalization. On this account it seemed better to follow the method of the "Manual of Water Works Practice" and plot the required filtered water storage against the total filter capacity.

The filter capacity is expressed as a function of the annual average pumpage, that is, if the annual average pumpage of a plant were 200 m.g.d., a filter ratio of 1.30 would mean that the total continuous net filtering capacity of the plant were 260 m.g.d. During the most extreme hour on record, the rate of pumpage was 180 per cent of the annual average flow, thus if a filter plant has a

capacity of 180 per cent of the annual average pumpage, no filtered water storage would be required for equalizing puposes. The filter ratio could not be less than one, therefore the economical ratio must lie somewhere between 1.0 and 1.8.

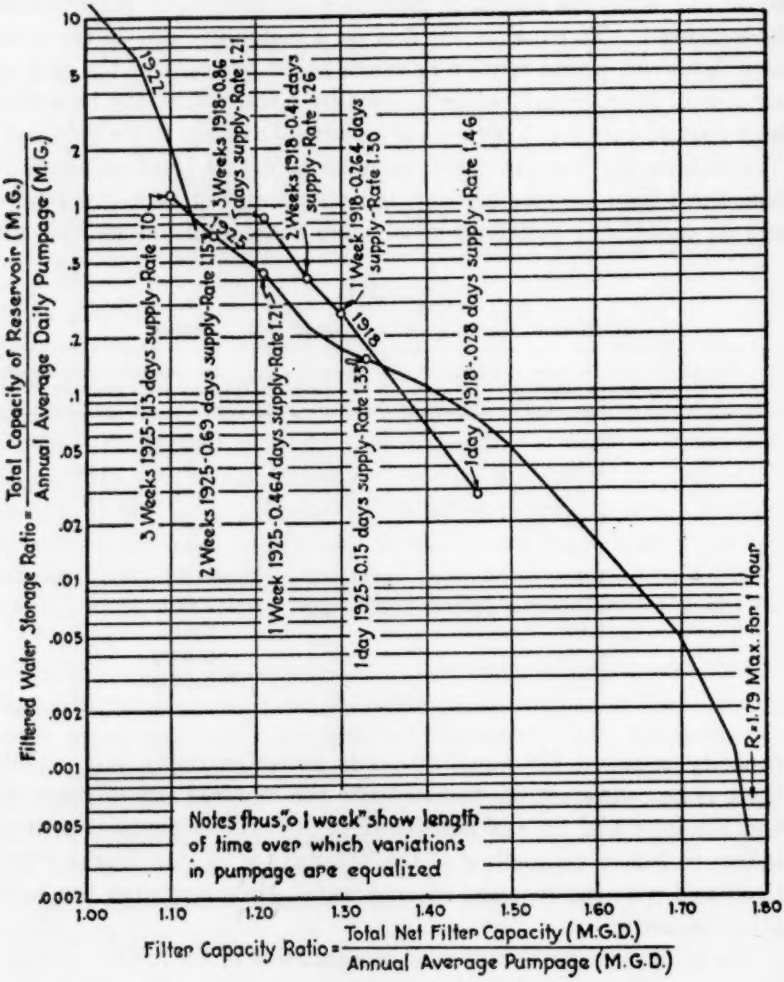

FIG. 1. RELATION BETWEEN FILTER CAPACITY AND FILTERED WATER STORAGE

The size of filtered water reservoir is expressed as a function of an annual average day's pumpage, that is, in a plant having an annual average pumpage of 200 m.g.d., a filtered water storage ratio

of 1.00 would mean a reservoir capacity of 200 million gallons. A filtered water storage of 0.16 would mean a capacity of 32 million gallons.

The experience of any given extreme period could be plotted as a line on the chart. The uppermost of any of these lines is the one to be considered in design. For Detroit the period in February, 1918, gives the most extreme conditions for filter capacity ratios less than 1.35. For all ratios greater than this, the period in June, 1925, gives the most extreme conditions.

The diagram shows that to operate the filter plant at a uniform rate throughout the entire year, would require a filtered water storage of at least thirteen days' supply, or for Detroit at present, about 2600 million gallons. This of course is quite out of the question. Table 1 gives some typical values taken from figure 1.

EFFECT OF STORAGE ON REQUIRED FILTER CAPACITY

Assuming a plant having an annual capacity of 200 m.g.d., it appears from the first two lines of the table that a decrease in filter capacity from 220 to 200 m.g.d., would require an increase in reservoir storage of 9.3 average days' supply, or 1860 million gallons, which would be obviously uneconomical. At the bottom of the list it appears that a storage of only 0.016 days' supply or 3.2 million gallons would make it possible to decrease the total filter capacity from 1.79 to 1.60, or more than 10 per cent, which would be obviously economical. Thus it appears that the economical filter capacity for any given plant, will be somewhere between 1.10 and 1.60 times the annual average pumpage.

ECONOMICAL FILTER AND RESERVOIR SIZES

If the cost of filter plants per million gallons daily capacity can be determined with reasonable accuracy, and also the cost of filtered water storage reservoirs per million gallons capacity, the data on figure 1 make it possible to determine readily the economical filter and reservoir sizes. Estimates for the Springwells Station of the Detroit system indicate that the probable costs, including land, will be about $13,000 per million gallons daily capacity for the filter plant and about $25,000 per million gallons capacity for the filtered water reservoir. Using these unit prices, and considering only the cost of the reservoir and of the filter plant, it will be found that the

minimum total cost is obtained when the capacity of the filter plant is about 1.35 times the annual average pumpage, and the capacity of the reservoir is about 14 per cent of an annual average day's supply.

In this discussion, it has been assumed that minimum first cost is the proper criterion for greatest economy, considering that the operating cost will be little affected by the relative capacity of the filter plant and the filtered water reservoir.

In general the existence of expensive intake works and long supply tunnels tends to make the economical filter ratio lower, and to require a larger reservoir, so that the tunnel and intake works may be operated at full capacity for a larger proportion of the time. With a conduit such as was proposed from Lake Huron to Detroit this might have an important effect, but in the case of the Springwells Station, computation shows that the effect is not very great, and that the economical filter ratio in this case also is close to 1.35.

This is due to the fact that the combined cost of filter plant and reservoir increases rapidly as the filter ratio is made less than 1.35, and very rapidly if the ratio is made less than 1.30. It appears certain that for Detroit conditions, it will never be economical to use a filter ratio of less than 1.30, corresponding to a filtered water reservoir capacity of 26 per cent of an annual average day's pumpage. This figure, it should be noted, refers to equalizing storage only. It will doubtless often be desirable to provide additional storage for reserve in case of accident.

WATER WORKS PARK STATION

A study was also made of the economical extent of development of the existing plant at Water Works Park, Detroit, considering only the cost of intake tunnel and equipment at Water Works Park and disregarding the effect of the distribution system. Assuming the maximum continuous filter capacity as 360 m.g.d. it appears that the existing plant, with the addition of two high lift pumps now under contract, will be able to supply at all times an annual average pumpage of 240 m.g.d., corresponding to a filter ratio of 1.50. By very considerable increases in reservoir storage capacity and high-lift pumping capacity, the same filter plant and intake works could be made to supply an annual average of 277 m.g.d., corresponding to a filter ratio of 1.30.

TABLE 2

Total reproduction cost of Water Works Park plant per million gallons daily capacity

Filter rate	1.80	1.50	1.44	1.40	1.38	1.35	1.325	1.30
Annual average in million gallons daily	200.0	240.0	250.0	257.0	261.0	267.0	272.0	277.0
Required storage (No. of days supply)	0.00	0.050	0.082	0.105	0.118	0.138	0.188	0.264
Total reservoir capacity, million gallons	0.00	12.0	20.5	27.0	30.8	36.8	51.0	73.1
New reservoir capacity, million gallons						5.8	20.0	42.1
Cost of utilizing existing reservoir			$116,000	$122,200	$126,000	$126,000	$126,000	$126,000
Cost of new reservoir at $25,000 per million gallons						$145,000	$500,000	$1,050,000
Maximum hourly rate in million gallons daily	360.0	432.0	450.0	463.0	470.0	480.0	490.0	495.0
Present pump capacity	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
Additional pump capacity	60.0	132.0	150.0	163.0	170.0	180.0	190.0	195.0
Cost of additional pumps at $4360 per million gallons	$262,000	$575,000	$653,000	$710,000	$740,000	$784,000	$827,000	$850,000
Cost of reproduction of existing plant	$12,547,000	$12,547,000	$12,547,000	$12,547,000	$12,547,000	$12,547,000	$12,547,000	$12,547,000
Total costs	$12,809,000	$13,122,000	$13,316,000	$13,379,200	$13,413,000	$13,602,000	$14,000,000	$14,573,000
Costs per million gallons daily	$64,000	$54,700	$53,400	$52,000	$51,400	$50,800	$51,400	$52,500

Before 1930 an annual average of 250 million gallons daily is expected. Filter Capacity 360 million gallons daily.

Existing Reservoir—35 million gallons of which 12 million gallons is now available for storage. About 31 million gallons can be made available.

For these two and several other conditions, the total costs of reproduction of the existing plant and the proposed additions were estimated. These data are shown in table 2. Dividing the total cost of reproduction by the annual average capacity, the total first cost per million gallons daily of annual average capacity was calculated. It will be noted that this figure is $54,700 for a filter ratio of 1.50, decreasing to a minimum of $50,800 for a filter ratio 1.35, and then increasing to $52,500 for a filter ratio of 1.30.

From this it is concluded that, from the point of view of the plant itself, the Water Works Park Plant should be developed to supply an annual average of 267 m.g.d., which would require filtered water storage for equalizing purposes alone of 37 million gallons. If it is agreed that there should also be in reserve, in case of accident, a volume equal to the pumpage of the maximum hour, this will amount to 1.80 times 267 divided by 24, or about 20 million gallons, making a total required reservoir capacity for both equalizing and reserve of 57 million gallons.

The present filtered water reservoir has a total capacity of about 35 million gallons, nearly all of which will be made available by the alterations now in progress. The proposed new reservoir will give additional storage of nearly 20 million gallons, making a total of about 55 million gallons or practically the amount shown by the above computation.

EFFECT OF ELEVATED TANKS

Study of figure 1 gives also an idea of the effect which elevated tanks of a given size would have in decreasing pressure losses in the distribution system during maximum hour pumpage. The diagram represents conditions in the city as a whole, however, whereas conditions in individual districts probably are more extreme. Nevertheless the diagram probably indicates in a general way the effect that storage in the distribution system would have.

Where there is no storage, as at present, the high-lift pumps and the entire distribution system must be able to supply water at 1.80 times the annual average capacity. To reduce this figure to 1.60, or by more than 10 per cent, would require a total reservoir capacity in the distribution system of only 1.6 per cent of an annual average day's pumpage or about 3.2 million gallons under present conditions. It appears possible to obtain this amount of storage in elevated

tanks, and the result would be a very great improvement in pressure conditions in times of emergency. A 10 per cent decrease in the total quantity supplied by the mains leading out of the station would result in approximately 20 per cent decrease in the loss of head in those mains, so that the minimum pressures in the distribution system during maximum hour would be improved by 5 or 10 pounds.

SUMMARY

This study showed that additional filtered water storage is not as valuable as was at first expected. As the filter ratio falls below 1.30 the necessary storage required increases so rapidly that the total installation is more expensive. Very large reservoirs are used in some cities, but they are justified either because of the purification obtained by storage, or because the flow of the source of supply is at times inadequate, and water must be stored to tide over periods of low flow. Large reservoirs are also of great value because of the additional security that they give. Many cities have several days' supply stored in elevated reservoirs, so that they need have no fear of serious difficulties due to any accidents to machinery or otherwise which can be repaired in a day or two.

To provide this additional security for Detroit would be quite out of the question. Dependence must in the future be placed on direct pumping as it has been in the past, using every effort to maintain the greatest possible reliability in the pumping system. The proper functions of a filtered water reservoir, under Detroit conditions, are therefore to equalize the flow to such an extent as economy indicates, and to provide a small reserve for emergencies.

The present investigation also showed that the economical filter ratio is about 1.35, probably not less, and possibly a little more. This means that the Water Works Park Plant might be economically developed to supply an annual average of 267 m.g.d. Assuming that the Springwells tunnel is designed to have a maximum capacity of 300 m.g.d., the analysis indicates that the maximum annual average amount of water which can profitably be supplied from the Springwells site, is 222 m.g.d. In each case the reservoir storage for equalizing purposes should be about 14 per cent of an annual average day. The one hour reserve amounts to about 7½ per cent of an annual average day, so the total reservoir capacity for all purposes should be about 21½ per cent of an annual average day.

GENERAL APPLICATION

The conclusions from the above study are of course based on a single set of conditions and will apply only partially or not at all under other circumstances. They apply particularly to direct pumping systems and to the larger plants where first cost is an important factor and salaries and wages are relatively less important. In very small plants it may be economical to have the filters and reservoir of such capacity that it is necessary to operate the filters for only a part of the day. The saving in salaries and wages may outweigh the difference in first cost.

The curve showing the relation between filter capacity and required filtered water storage will be very different for some cities from that shown in figure 1. In particular the filter capacity ratio corresponding to zero storage, that is the ratio of maximum hourly pumpage to annual average, is usually much higher than 1.80. This ratio appears to be generally more than 2.00, and in one case it has been found to be as high as 3.22 for a city of over 300,000 population. Large cities will as a rule have smaller ratios than smaller cities. Night operation of industries also tends to smooth out the water consumption curve. Elimination of waste is of course a desirable end, but in this connection it has an undesirable effect, in that it makes peak hours relatively higher than before.

If a study of this kind is based on adequate local data, it gives information of great value in determining the economical capacity of filter plant and size of filtered water reservoir. Consideration must be given to the necessity of a reserve in case of accident, and to the fire demand which would result from a conflagration in cities of such size that this has an important effect on the result. If this is done the method of analysis gives real information as to the capacities required, and adequate water supply is assured without unnecessary expenditure either for the filter plant or for the filtered water reservoir.

THE USE OF STANDPIPES AND ELEVATED TANKS TO REINFORCE THE DISTRIBUTION SYSTEM DURING PERIODS OF HIGH DEMAND[1]

By Nicholas S. Hill, Jr.[2]

There are, of course, many kinds of reservoirs, but this paper is intended to deal only with those reservoirs connected with the distribution system and designed to equalize loads on sources of supply, pumping stations, filtration plants and the like, as well as upon transmission and distributing mains. Standpipes and elevated tanks belong to this class of reservoir.

If due consideration is given to properly located distributing reservoirs it will frequently be found that a reduction in first cost of the elements above enumerated may be secured. As a matter of fact, the economic value of storage located at strategic points on the distribution system is not appreciated as it should be. It is not uncommon when pressures are deficient to expend large sums to reinforce existing mains when the same result might be obtained at a smaller expenditure for proper storage. It is also common to see pumping stations, filtration plants and the like designed to meet peak demands on a water system when the introduction of storage would equalize the load on them, and not only reduce the initial capital outlay required for their construction but operating costs as well.

Let me cite a few examples of the use of storage in reducing cost. If it is necessary to deliver water through a long transmission main it is often possible to reduce its size if properly located storage on the distribution system may be counted on to meet the peak loads, or the effective service of an existing line may be improved by relieving it of the high friction losses which occur at peak loads.

The introduction of storage may reduce the first cost of installing new pumping stations or filtration plants, or the effective capacity of existing plants may be increased.

[1] Presented before the Buffalo Convention, June 8, 1926.

[2] Consulting Engineer, New York, N. Y.

The effective yield from wells may also be increased, and sometimes the quality of water improved.

In small plants the provision of proper storage will permit of part-time operation, thereby reducing the cost of attendance and other operating charges.

Short time interruptions for repairs and adjustments may be made in larger plants where there is local storage.

Local friction losses in the distribution system may be greatly reduced by properly placed storage and hence pressures may be increased during periods of heavy demand without making expensive reinforcements.

A standpipe or an elevated tank often solves the problem of providing adequate service in outlying territory where the cost of the piping necessary without it would be prohibitive.

The amount of water to be stored, its location and elevation are local problems and the determination of these questions should be the result of local studies, but storage makes the operation of a water system more elastic as the load upon the source, pumping stations or filtration plants does not have to synchronize with the fluctuating demand on the distribution system.

The problem of properly placed distributing storage is an economic one in which the fixed charges and maintenance costs on the storage reservoirs must be balanced against the saving in fixed charges and operating expenses which they will effect. The amount of distributing storage to be provided in any given case will, therefore, depend upon local conditions, but it is undoubtedly true that in the great majority of plants provision for a certain amount of it will reduce not only fixed charges but operating expenses.

It is not my purpose to present a lengthy paper, but rather to give a few illustrations which will show the principles involved in placing storage at strategic points on the distribution system and its effect upon operating conditions.

For the purpose of illustration I have taken a city of 50,000 people using an average of 5 million gallons per day and requiring fire service at a maximum rate of 7 million gallons per twenty-four hours on a day of maximum consumption.

Table 1 gives the ratio of consumption rates during periods of varying length to the average yearly rate. This relation will vary with local conditions, but for the purposes of this paper the table may be taken as typical.

The variations in consumption shown in this table are most important in ascertaining what proportion of the peak loads may be economically supplied through the introduction of storage. From this table it is seen that under the assumption heretofore made the rate of consumption on the maximum day would be approximately 7 million gallons, and with an equal amount to meet maximum fire service requirements a conservative design, with no storage, would call for sources, pumping stations, filter plants and transmission or supply mains which would deliver water at the rate of 14 million gallons daily for several hours at a time,—that is, a

TABLE 1

Relation of rates of water consumption to average for the year

FOR PERIOD COVERING (1)	PER CENT RELATION OF AVERAGE RATE FOR PERIOD TO AVERAGE FOR YEAR (2)	FOR PERIOD COVERING (1)	PER CENT RELATION OF AVERAGE RATE FOR PERIOD TO AVERAGE FOR YEAR (2)
1 year	100	2 days	137.5
10 months	102	1 day	140.0
8 months	104	22 hours	144.0
6 months	106	20 hours	148.0
4 months	108	18 hours	152.0
2 months	110	16 hours	156.0
1 month	111	14 hours	161.0
4 weeks	113	12 hours	167.0
2 weeks	121	10 hours	173.0
1 week	125	8 hours	179.0
6 days	127.5	6 hours	185.0
4 days	132.5	2 hours	197.0

plant which would have a capacity to meet the maximum daily average consumption plus the maximum fire service demand.

Computations show that a storage of 1,725,000 gallons will provide for the fire service requirements for six hours and will cost but $45,000.

If the fire requirements are met by storage, therefore, the capacity of the transmission mains, pumping stations and filter plants could be reduced from 14 to 7 million gallons daily. Such a reduction in capacity would effect a saving of possibly $18,000 per mile of transmission main.

It is obvious, therefore, that the saving on a few miles of trans-

mission main would more than offset the cost of the storage required for fire protection purposes only.

In a plant which I recently designed for Tampa, Florida, it was found that by spending approximately $85,000 for storage on the distribution system to take care of fire service and maximum hourly peak loads a saving of $407,500, could be effected in the cost of installation of a pumping plant, filtration plant, and transmission main, or a net saving in the cost of installation of $322,000. The estimated saving in operating expenses by reason of the more uniform operation at the pumping station and the reduction in the head it was necessary to pump against on account of the introduc-

TABLE 2

Relation of hourly rate of water consumption to average for the day

TIME (1)	PER CENT RELATION TO AVERAGE FOR DAY (2)	TIME (1)	PER CENT RELATION TO AVERAGE FOR DAY (2)
7– 8 a.m.	106	7– 8 p.m.	88
8– 9 a.m.	129	8– 9 p.m.	86
9–10 a.m.	135	9–10 p.m.	86
10–11 a.m.	139	10–11 p.m.	86
11–12 a.m.	143	11–12 p.m.	84
12– 1 p.m.	123	12– 1 a.m.	75
1– 2 p.m.	124	1– 2 a.m.	75
2– 3 p.m.	116	2– 3 a.m.	68
3– 4 p.m.	112	3– 4 a.m.	68
4– 5 p.m.	109	4– 5 a.m.	75
5– 6 p.m.	105	5– 6 a.m.	80
6– 7 p.m.	92	6– 7 a.m.	95

tion of storage was about $7,000, which capitalized at 10 per cent means an additional saving of $70,000, or a total saving of $392,000.

These figures clearly indicate that broadly speaking a moderate investment in storage reservoirs will save appreciable amounts of capital outlay in pumping station, filter plant and transmission mains. They also show that this is not the only effect, but, by making it possible to operate the pumping station and filter plant at nearly uniform rates, operating costs may be curtailed.

Table 2 shows the relation of the hourly rates of consumption to the average daily rate and shows a variation from 68 per cent of the average during the night hours to 143 per cent during the day

hours. It illustrates the varying conditions which must be met when pumping into a distribution system without storage. These percentages do not include fire service peaks. Figure 1 shows graphically the percentages in Table 2 and illustrates the possibility of levelling the pumpage rates.

If distributing storage equal to one-half hour's pumpage at an average daily rate of 5 million gallons, or about 100,000 gallons,

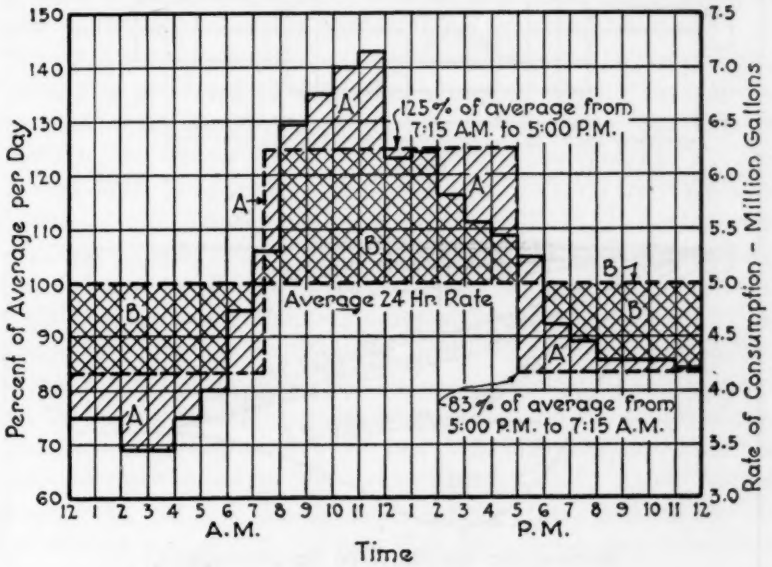

FIG. 1. HOURLY VARIATION IN WATER CONSUMPTION

To pump at uniform rate from 7:15 a.m. to 5:00 p.m. requires storage equal to approximately one-half hour's supply at average daily rate or 5,000,000 average rate for twenty-four hours requires 100,000 gallons effective storage.

To pump at uniform rate for twenty-four hours requires storage equal to approximately two and one-half hours' supply at average daily rate or 5,000,000 average rate for twenty-four hours requires 500,000 gallons effective storage.

were provided on the hypothetical system, the pumps could be run at 25 per cent above the average from 7.15 a.m. to 5 p.m. and at 17 per cent below the average from 5 p.m. to 7.15 a.m., as indicated by the pumpage curve "A" on figure 1.

The diagram illustrates how much simpler it is to operate a pumping station and filter plant at a uniform rate for long periods of the

day and night and without the necessity of changing from hour to hour which would be necessary without storage. A 100,000 gallon elevated tank which would effect this result under the conditions named would cost only $8000. If to this 100,000 gallons sufficient

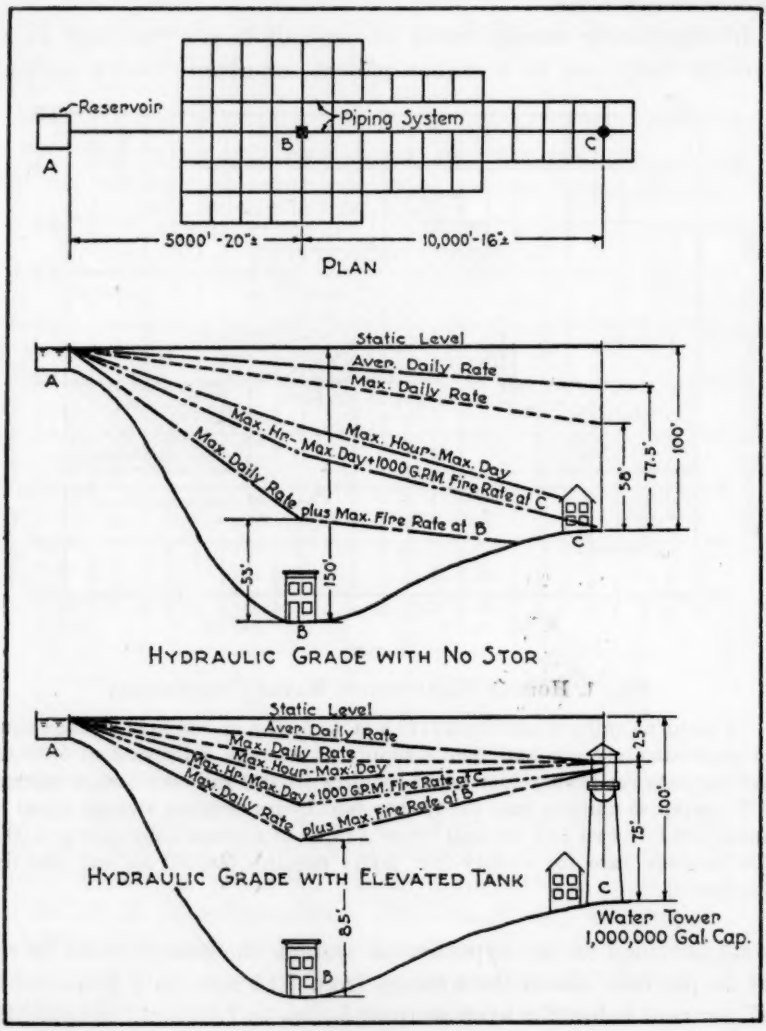

FIG. 2. HYDRAULIC GRADIENT WITH AND WITHOUT STORAGE
5,000,000 gallons per day average consumption for year.
7,000,000 " " " " " maximum day.
7,000,000 " " " " maximum rate of fire supply.

storage were added to meet the fire demands a pumping station and filtration plant with an average capacity of 5 million gallons daily could be made to operate at a uniform rate through the day hours and night hours. By introducing larger amounts of storage the rates of pumpage during the day and during the night could be made more nearly uniform, and if it were found economical to do so sufficient storage could be installed to enable the filter plant and pumping station to operate at a uniform rate through the twenty-four hours of the day, as shown on Line "B," figure 1.

Low pressure is a fault commonly found in water works systems. Figure 2 is presented to illustrate a way in which this may be remedied by the introduction of storage. At the top of the diagram a distribution system is shown in plan with a reservoir at "A," the business district and centre of distribution at "B" and the residential district remote from the source of supply at "C." In the centre of the diagram the hydraulic gradients between "A" and "C" resulting from different conditions of draft without storage are shown, and at the bottom the hydraulic gradients between "A" and "C" resulting from different conditions of draft with storage are indicated. For the purpose of computing the hydraulic gradients it was assumed that the piping system between the reservoir and the centre of distribution was equivalent to 5,000 feet of 20-inch pipe, and from the centre of distribution to the residential district to 10,000 feet of 16-inch pipe. It was also assumed that the static pressure at "B" was 150 feet, ar[illegible] "C" 100 feet, that the average daily consumption was 5 mil[illegible]llons, and that the maximum fire service was at the rate of 7 million gallons daily as before.

The hydraulic gradients without storage clearly show the effect of the assumed drafts upon the pressures at "B" and "C" under the conditions assumed. The deficiency in pressures at the higher rates indicated could be remedied by laying larger mains from the reservoir at "A" through the business section to the residential section at "C," but it may also be remedied at less cost by the installation of an elevated tank at "C" as shown by the hydraulic gradients after the elevated tank is installed.

Comparison of the hydraulic gradients before and after the installation of storage clearly indicates the beneficial effect which it has upon the pressures, not only at "C" but at "B" and throughout the distribution system. Local pressure deficiencies in parts of a large distribution system may in many cases be similarly remedied by the location of elevated tanks at strategic points.

Figure 3 is presented for the purpose of illustrating the effect of storage on the distribution system upon the operating conditions at a pumping plant, as well as to show the effect of the location of the

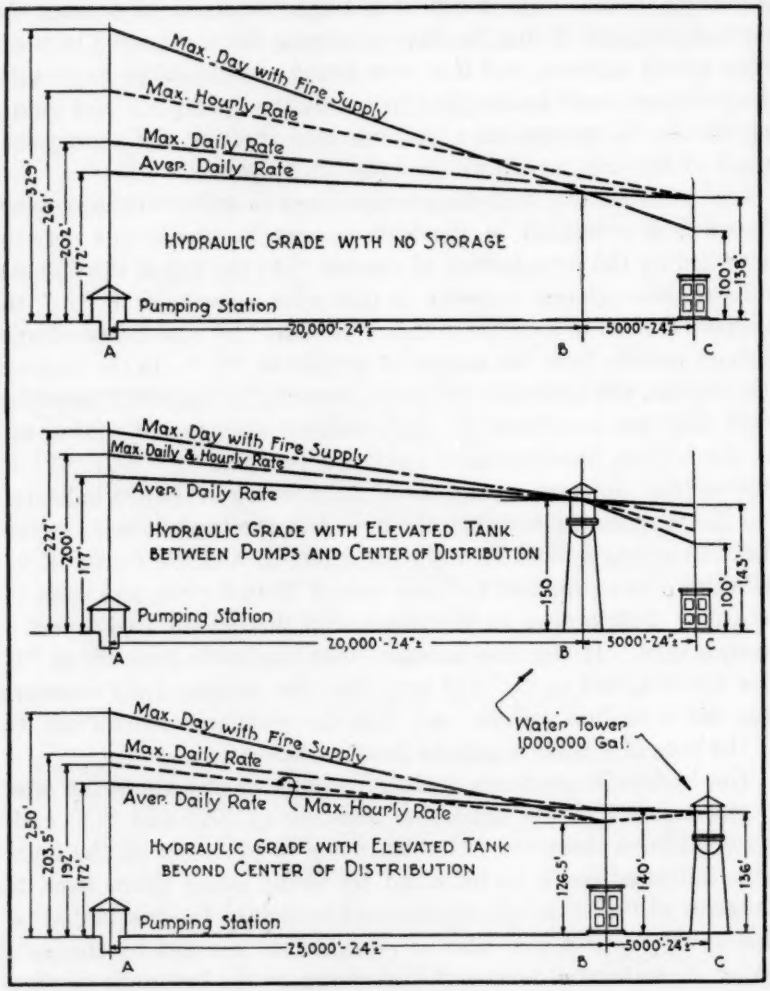

FIG. 3. EFFECT OF ELEVATED TANK ON DISTRIBUTION PRESSURES

tank upon pressures at the centre of distribution. It has been assumed that water is pumped to the city through a combined piping system having a discharge capacity equivalent to 25,000 ft. of 24-inch pipe. The average daily consumption and fire require-

ments have been taken at the same rates as those used in the previous illustration. From the hydraulic gradients with no storage it will be noted that it is necessary to maintain pressures at the pumping station "A" ranging from 172 to 329 feet if an ordinary pressure of 60 pounds (138 feet) and a fire pressure of 43.4 pounds (100 feet) are to be maintained at the centre of distribution "C."

If an elevated tank with a storage capacity of 1 million gallons and 150 feet high were placed at "B," the hydraulic gradients would be as shown on the profiles marked "Hydraulic Grade with Elevated Tank Between Pumps and Centre of Distribution." By comparison of the hydraulic grades with no storage and those resulting from the introduction of an elevated tank at "B," the pressures at the pumping station required to maintain equivalent pressures at the centre of distribution "C" may be reduced from 60 to 100 feet under the maximum conditions of operation.

The profiles marked "Hydraulic Grades with Elevated Tank Beyond Centre of Distribution," "C," show that more uniform pressures may be maintained at "B" with a tank of the same capacity as that proposed for scheme B but 14 feet lower, and the pressures at the pumping station will range from 172 to 250 feet.

A comparison of the hydraulic gradients with and without storage indicates clearly that storage not only reduces the fluctuations in demand upon the pumping station but also equalizes the pressures against which water must be pumped to maintain a given pressure in the distribution system. The effect of reducing the pressures at the pumping station, of course, not only means a saving in fuel but pumps of less rugged construction and hence less costly, and transmission mains of less thickness, all of which reduces the capital cost.

The diagram also illustrates the effect of changing the location of the storage on the distribution system and illustrates how the best results may be obtained by a careful study of local conditions before selecting the site for a proposed storage tank.

The foregoing are but a few examples of many which might be presented for illustration. No good would come, however, from a multiplication of this kind. The ones submitted illustrate the principles involved.

AUTOMATIC HYDROGEN-ION CONTROL OF BOILER FEED WATER[1]

By Henry C. Parker[2] and Willard N. Greer[2]

INTRODUCTION

Due to the development and the increasing use of boilers operating at high ratings and temperatures, the subject of boiler feed water conditioning has become of increasing importance during the last few years. The advance of knowledge in, and the improvement of methods for, the chemical treatment of boiler feed water have not kept pace with the more exacting requirements of such treatment. Chemists are only beginning to realize that they must go beyond the conventional chemical precipitation equations and make a study of chemical equilibria[3] at high temperatures and pressures—a subject about which our present knowledge is very limited. Present day problems demand a knowledge of thermodynamics and an understanding of the use and significance of electrolytic conductivity and hydrogen ion methods and measurements. If chemists fail to solve the problems involved, there will undoubtedly be a gradual tendency toward the ultimate use of distilled water both for cooling and make up purposes. By no other means will the necessity for chemical treatment be eliminated and not entirely even then.

A proper understanding of chemical equilibrium demands the knowledge and study of *ion* concentrations which can, at present, be best determined by conductivity or electromotive force measurements. The most important of these measurements is undoubtedly that of the H-ion concentration, and this quantity is fortunately capable of exact and easy determination, at least at ordinary temperatures. Before H-ion measurements were introduced it was necessary to approximate this factor by titrations to the phenolphthalein or methyl orange end points, and with expressions such as

[1] Presented before the Boiler Feed Water Studies Session, Buffalo Convention, June 9, 1926.

[2] Research Department, Leeds & Northrup Company, Philadelphia, Pa.

[3] Hall: J. Ind. Eng. Chem., 17, 283 (1925).

"mono-carbonate alkalinity," etc. It is to be hoped that these approximate methods will soon be superseded by the more exact measurement of H-ion concentration or pH $\left(= \log \frac{1}{\text{H-ion concentration}}\right)$.

APPARATUS AND METHOD OF OPERATION

Several years ago, in coöperation with the Public Service Electric and Gas Company, it was attempted to apply the aspirator type of air electrode to the automatic H-ion control of boiler feed water[4] at their station in Perth Amboy. Operating experience with this apparatus proved that this type of electrode was not suitable for general commercial application. The electrode was found to become quickly "poisoned" by oil and other substances commonly found in boiler feed water. It was also found that the platinizing of the electrodes, renewal of the calomel cell, the keeping of a slow but steady flow of standard KCl solution, and the use of a filter required an amount of time and skill which were not warranted in industrial practice.

The recent development of improved calomel cells[5] and tungsten electrodes[6] removed the operating difficulties mentioned above and reduced the attention required to a minimum. The successful use of the tungsten electrodes in recording the pH of potable water,[7] and in the control of the addition of lime in the Direct Oxidation method of sewage disposal,[8] showed the practicability of the control and foreshadowed its successful operation.

It was necessary, however, to develop a new type of control. In previous installations, a control, which may be called the "on-off" type, had been used. This control operates with a by-pass sufficient to care for the minimum requirements of the system, while the control valve supplies an excess. That this type of control would prove unsuitable was evident when it was found that the rate of flow of the chemical (caustic soda) was only about three gallons per hour.

The new control developed may be called the "time lag, proportional step" type. This type controls the entire supply of chemicals

[4] Arthur and Keeler: Power, **55**, 768 (1922).
Keeler: J. Ind. Eng. Chem., **14**, 1010 (1922).
[5] Parker and Dannerth: J. Ind. Eng. Chem., **17**, 637 (1925).
[6] Parker: Ibid., **17**, 737 (1925).
[7] Parker and Baylis: J. Am. Water Works Assoc., **15**, 22 (1926).
[8] Parker: Trans. Am. Inst. Chem., Eng., **16**, (2) 231 (1924).

and has a valve which opens or closes gradually until a point is reached where the flow is sufficient to care for the requirements of the system. With this type of control a time lag feature is quite essential and this was supplied in the recorder-controller mechanism. This feature allows time for the solution around the electrodes to reach the concentration corresponding to the last operation of the valve before the control again corrects the valve opening.[9]

Photographs of the complete automatic apparatus are shown in figures 1 and 2. The recorder-controller and control valve, shown in figure 1, are located at the base of the surge tank, while the apparatus shown in figure 2 is located on the floor below, just in front of the feed water heaters. The chemical supply line is shown at the right side in figure 1. After passing through the automatic valve, which is operated by the gear reduction (the motor is behind the relays in figure 1), the chemicals enter the top of the feed water heaters where thorough mixing occurs. A bleeder takes a sample of feed water from the bottom of the heaters, and this enters at the top of the apparatus shown in figure 2. It passes through an overflow device to obtain a constant head, then through a cooling coil and into the bottom of the flow channel, where it comes in contact with the electrodes, calomel cell and thermometer. After passing through the flow channel it overflows into the waste funnel from which it is discharged into one of the make up lines.

The feed water sample requires cooling to a fairly constant temperature which is maintained by adjusting its flow through the cooling coil two or three times a day. If greater accuracy in control were desired, automatic temperature compensation could be provided, but this provision appears unnecessary at present.

The recorder-controller acts in two cycles—first recording and then controlling. The latter cycle lasts about one minute and the former five minutes. The timing of these cycles may be adjusted by a change of gears. At the start of the control cycle an auxiliary potential (determined by the position of the control setter) is substituted for the potential of the electrodes. (This potential corresponds to the potential of the electrodes, when the feed water is at the desired pH). Simultaneously, the motor circuit is closed through the relays and the valve starts to rotate in the proper direction to correct the feed water to the desired pH. When the recorder

[9] Parker: Ibid., p. 239.

carriage has come to balance at the point corresponding to that of the auxiliary potential, the motor circuit is again broken and the valve stops rotating. The operation of the valve is thus proportional to the time required for the recorder to move from the actual poten-

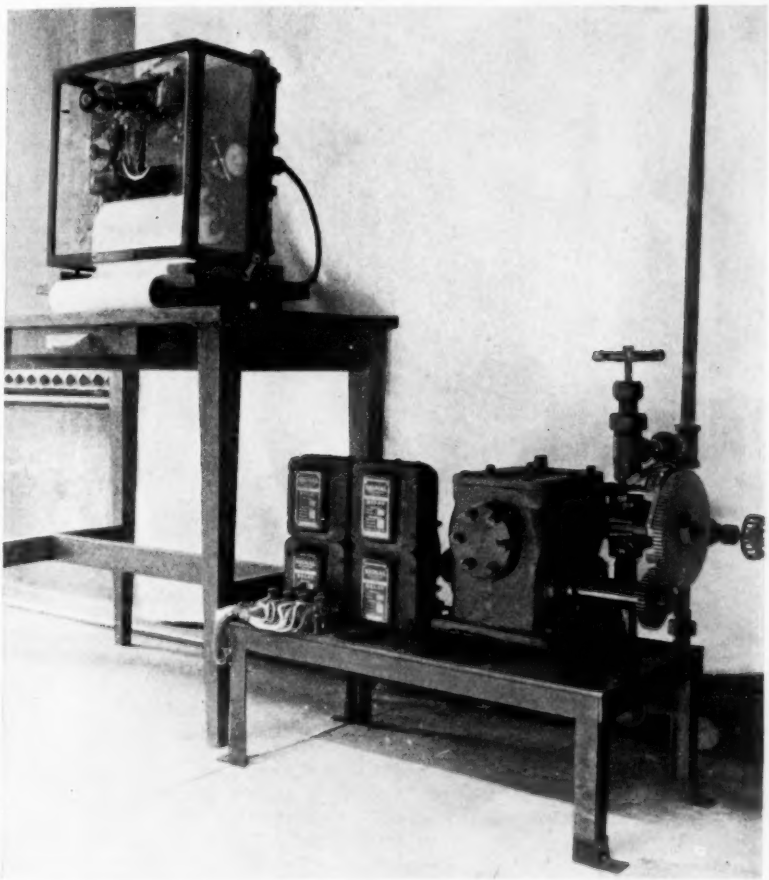

FIG. 1. AUTOMATIC pH RECORDER AND CONTROLLER

tial of the electrodes to the desired potential of the electrodes, and hence to the amount the pH is away from that required.

At the conclusion of the control cycle the electrodes are again thrown in circuit and the recorder balances at a point corresponding to the actual H-ion concentration of the solution. When the solution around the electrodes has had time to change in H-ion concen-

tration, corresponding to the new opening of the valve, the control cycle is again ready to operate.

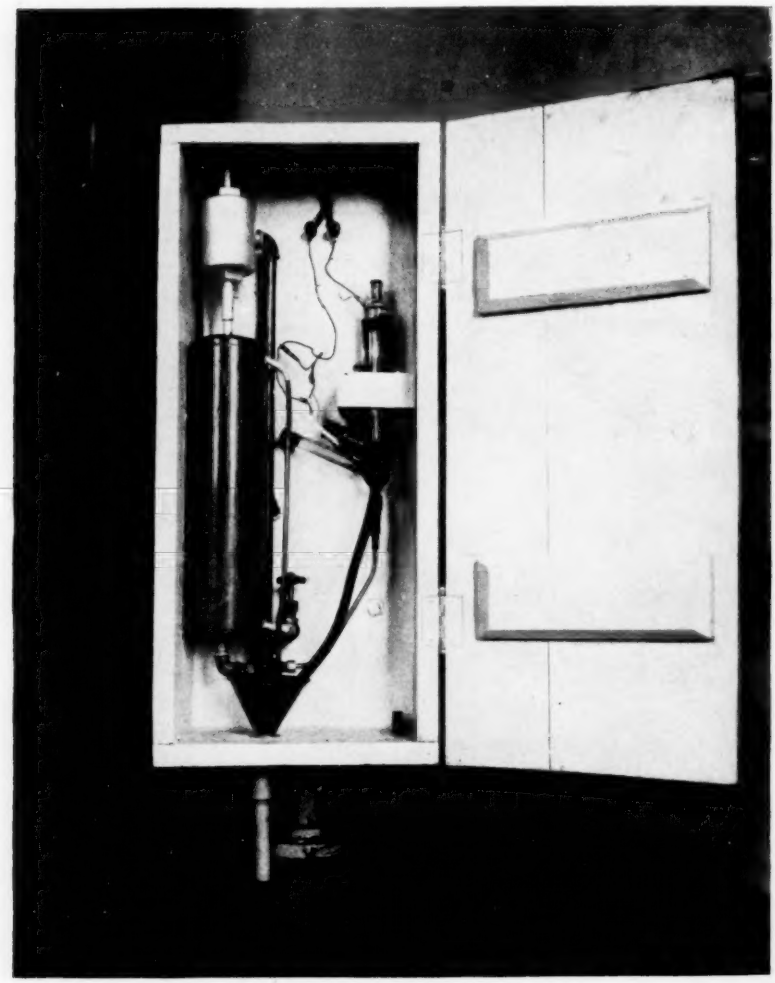

FIG. 2. ELECTRODES AND CALOMEL CELL

THE H-ION RECORD

The recording and controlling cycles can easily be distinguished by an examination of the twenty-four hour record shown in figures 3 and 4. At the points *a*, *b*, *c*, etc. the H-ion concentration is being

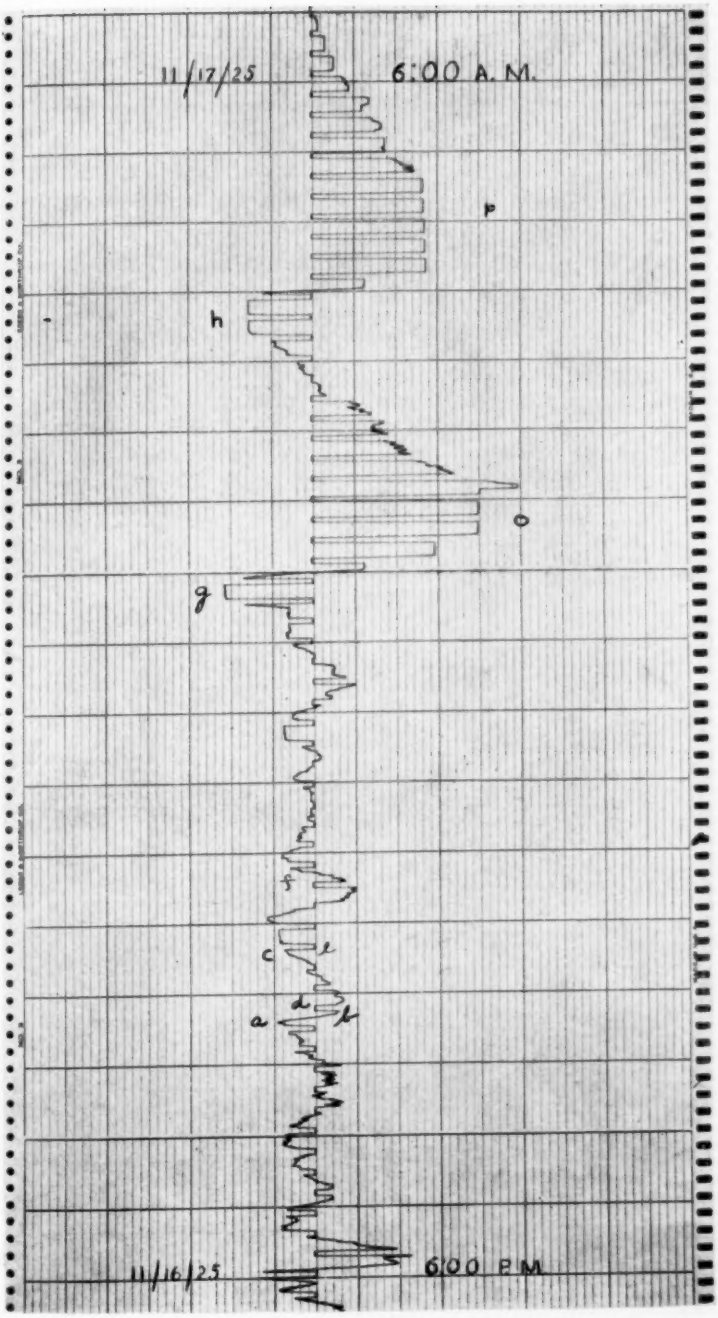

FIG. 3

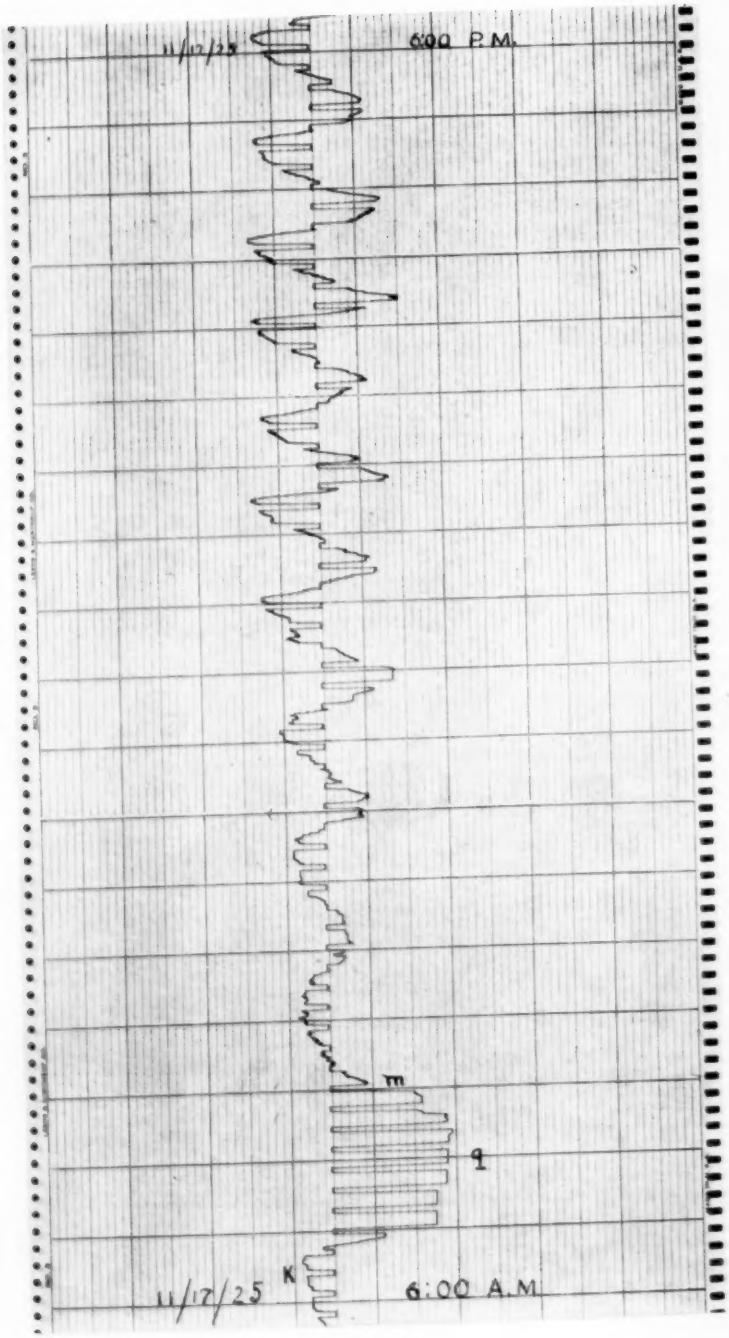

FIG. 4

recorded while the control potential is indicated at *d*, *e*, *f*,etc. The complete record can evidently be determined by drawing a continuous line through the points *a*, *b*, *c*, etc. The deviation from the desired H-ion concentration may be found by noting the distance of such a line from the voltage corresponding to that of the control point. At the left the pH is low, and at the right it is high. At about 12:00 p.m. the plant is shut down and it is evident that the last addition of caustic at *g* was sufficient to keep the water in the heater alkaline through most of the night. At the points *h* and *k*

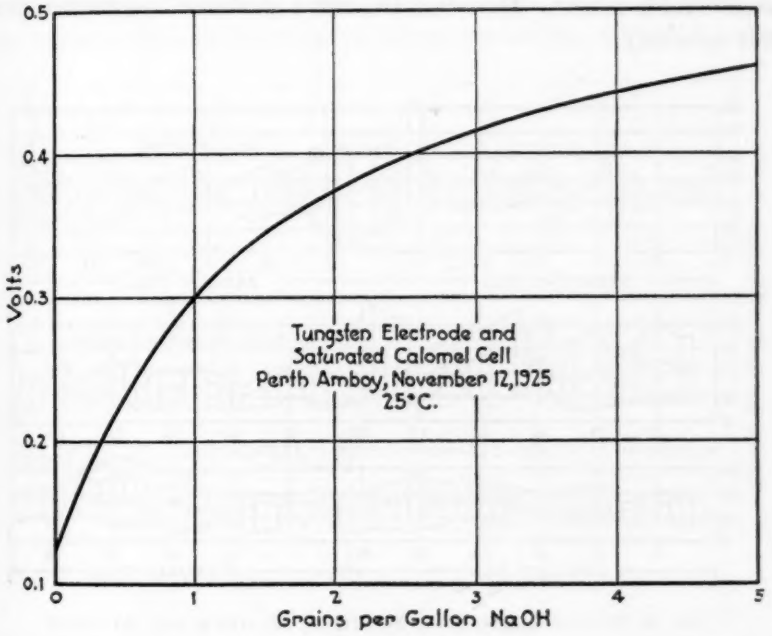

FIG. 5

(about 3:00 and 6:00 a.m.) the pumps started operating and raw water was drawn through the heater again causing the valve to open. Where the record remains at some distance to the right (points *o*, *p* and *q*) the caustic valve is completely closed. The water in the heater is evidently alkaline and remains so until more raw water is pumped through. When the record is running to the left of the control potential the valve is being opened at each control interval, while at the right the valve is being closed, unless already completely closed.

In order to interpret the recorder readings in terms of grams per gallon sodium hydroxide, the curve shown in figure 5 was determined. An all day average sample of the feed water was collected. Sodium hydroxide was then added in small quantities and the pH of each concentration was determined from the voltage readings of the electrode. This chart does not give universally true values of grams per gallon NaOH, since it is evident that if the character of the raw water were changed (about 10 per cent raw water is used at Perth Amboy) the lower section of this curve would be shifted to a considerable extent. However, the curve gives relative values with fair accuracy.

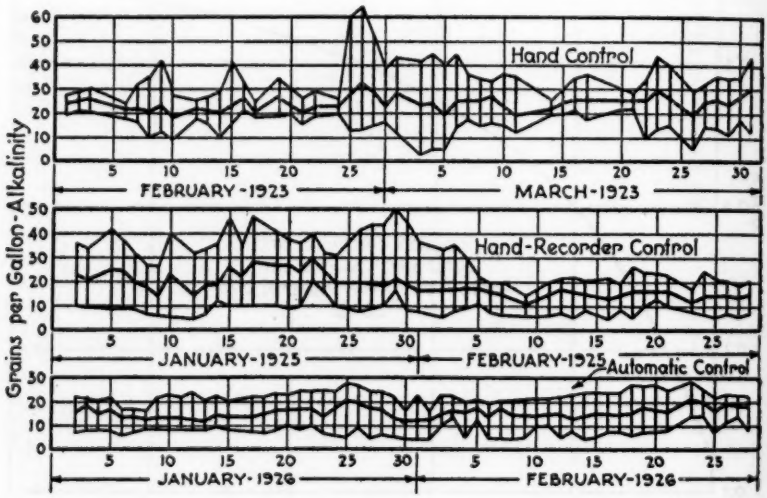

FIG. 6. BOILER ALKALINITY, MAXIMUM, MINIMUM AND AVERAGE

ADVANTAGES GAINED BY AUTOMATIC CONTROL

Unless the boilers in a station are treated with chemicals individually (a process which is both expensive and time consuming) there is bound to be developed considerable differences in the alkalinity of the different boilers. In case the feed water is treated without regard to variations in load, or to the proportion of raw water, these differences in alkalinity cause a considerable amount of unnecessary blow downs, in order to keep "high" boilers within reasonable limits of alkalinity. If chemicals are more or less "dumped" into the feed water system (which is another way of expressing their

addition without regard to load or acidity of the feed water) it is evident that the boilers which are taking more then their share of the load, at the time, will get the larger proportion of the chemicals. Hence we would expect, in this case, that there would develop a considerably greater difference in the maximum and the minimum alkalinities than if the feed water were under continuous automatic H-ion control. We should also expect that the maximum and minimum values, as well as the average alkalinity, would fluctuate more erratically without the H-ion control.

That these conclusions are correct is shown clearly in figure 6. In these curves the ordinates represent grains per gallon of boiler

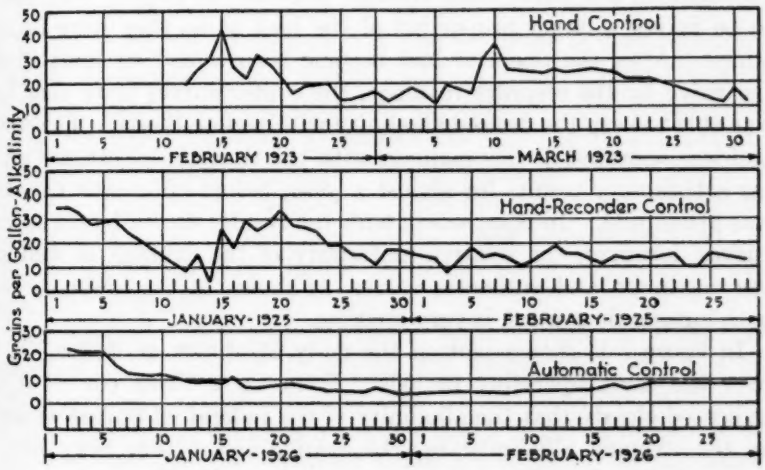

FIG. 7. SHOWING ALKALINITY OF BOILER NO. 1

alkalinity, determined by daily titration of the boiler water. The abscissas represent time, which extends over three different two month's periods in this chart. The circles give the average concentration of the boilers, while the upper curve shows the maximum and the lower the minimum daily alkalinity. When less than four boilers were operating, on a given day, the results are omitted. (The usual number operating was eight). The upper section of the chart shows the results obtained when the chemical feed was hand controlled, by means of an occasional titration, during February and March, 1923. The middle section gives the results obtained at the time when the tungsten electrodes were first being used with

the recording potentiometer, but before automatic control was attempted. During this interval the operator controlled the opening of the valve according to the recorder readings. The lower section (January and February, 1926) gives the operating results during automatic control.

The most striking change in the operating results upon the introduction of automatic control is the absence of sudden increases in alkalinity such as occurred during hand control on February 9, 15, 19, 25, 26 and March 16, 23 and 31. Such erratic changes in alkalinity were evidently caused by the addition of an excess of chemicals due to an improper opening of the valve, or by the introduction of more chemicals in one boiler than another, because the former happened to be taking a larger proportion of the load while they were being added. After the operator had become accustomed to controlling the valve by the recorder readings, the center curves show that he was able to keep the desired alkalinity within close limits. The control was operated in this manner, with the tungsten electrodes giving satisfactory results for almost a year, before automatic control was attempted. In comparison with the results shown by the upper curves, however, the relative uniformity of the average as well as the maximum and minimum values, as shown in the lower curves with automatic control, is very striking.

In figure 7 is shown plotted the daily alkalinity of Boiler No. 1 over the same operating periods. From these three curves it is indicated clearly that the alkalinity of the individual boilers as well as the average alkalinity can be maintained within very much closer limits by means of the automatic control.[10]

During the use of the tungsten electrodes the average alkalinity of the boilers has been safely reduced, due to the fact that the automatic control causes the addition of alkali to compensate for condenser leakage.[11] (Condenser leakage lowers the H-ion concentration and, in order to keep the pH of the feed water constant, the control automatically adds additional caustic as the leakage increases.)

[10] It may appear that the increase in uniformity was obtained by a more careful blow down schedule. This, however, would not prevent the sudden *increases* in alkalinity such as occur under hand controlled conditions. As a matter of fact the blow downs have, if anything, been reduced during the use of automatic control.

[11] Since this was written the feed water treatment has been changed to include sodium phosphate, and the boiler alkalinity has been raised. The automatic control has operated successfully under these new conditions.

In fact the alkalinity has been so far reduced that it would now be almost impossible to control the addition of caustic by titration. The alkalinity of the feed water is kept at a pH of approximately 7.5 which is, of course, below the phenolphthaline end point, and would be quite impossible to determine accurately by titration.

ROUTINE ATTENTION REQUIRED

While the tungsten electrodes were being used with the recorder, single electrodes were found to operate successfully over periods of two months or longer. Since the automatic control was started, a routine has been followed whereby one electrode is renewed every week. Two electrodes are run in parallel, positioned side by side in a two-holed rubber stopper. A new electrode is introduced into one of the smaller side tubes of the flow channel every Monday morning, but is not connected to the control. On Tuesday the oldest electrode is thrown away and the new one substituted and placed in the two-holed stopper. In this manner each electrode is run over a two weeks period, and each new electrode is allowed a period of 24 hours to reach equilibrium before being introduced into the circuit. If desired, the period of use could doubtless be considerably extended.

One calomel cell is kept in reserve while another is in use. On Monday and Thursday these cells are interchanged and the one which has been in use is flushed out, by removing the porous cup at the bottom and draining out a few drops of the saturated potassium chloride solution. The oil which has collected on the porous cup is then removed by scrubbing with soap and the cup is allowed to dry until again needed, when it is refilled with potassium chloride crystals and solution.

The current in the recording potentiometer requires checking once a day, and two or three times a day the flow of the feed water through the flow channel is adjusted. Due to the extremely small flow of chemicals, a valve is used with a series of $\frac{1}{64}$ inch orifices. These orifices require cleaning every two weeks.

Outside of the usual care required by a recorder, such as filling of the pen, renewal of the paper roll, etc., no other attention is demanded. The actual time required for the above manipulations averages probably thirty minutes a day or less.

THE FIELD OF USEFULNESS

The same type of control could doubtless be applied to the addition of soda ash, lime or sodium phosphate to boiler feed water, or to water softening problems in general. With soda ash the control (in grains per gallon) would probably be not quite as close, due to the fact that the change in pH for a given concentration would not be as great. However, with control as close as that obtained with the equipment described, it appears probable that caustic soda would prove just as reliable a chemical to use, and its use would undoubtedly result in a better grade of condensate.[12]

Another application of H-ion control for boiler feed water is found in those natural waters, and also in zeolite treated waters, where the alkalinity builds up to a dangerously high degree in the boilers. In these cases the H-ion control can be used for the addition of acids or acid salts[13] to hold the alkalinity within safe limits. By means of this control, if the alkalinity of the feed water increases, a larger amount of acid will be added automatically to keep the pH constant. This is the only type of control in which this desirable feature can be made automatically operative.

ADVANTAGES OF H-ION CONTROL

In a preceding paper[14] it has been pointed out that H-ion control of boiler water and boiler feed water is fundamentally more valid than that obtained by the use of "alkalinity" determinations, due to the fact that the former method makes allowance for the dissolved salts present. In control by "alkalinity" determinations an analysis of the salt content is required, in order to make any such allowance and any factors or ratios of boiler alkalinity to the concentration and composition of salts present would be based primarily upon conjecture.

Automatic H-ion control of boiler feed water also accomplishes one vital need which can be accomplished in no other way. This is the automatic addition of chemicals to the feed water in such proportion as to allow for condenser leakage. In the usual feed water

[12] In some investigations (Dow: Electric Light and Power, **2**, 69, 1924) it has apparently been shown that there is little or no difference between the action of caustic soda, calcium oxide, and soda ash (of the same causticity) in the prevention of corrosion and scale formation in boilers.

[13] Parr: Bulletin No. 94, p. 51, Engineering Expt. Sta., Univ. of Ill.

[14] Mechanical Engineering, November, 1926.

control sufficient additional chemicals must be kept in the boiler to allow for any sudden increase in condenser leakage such as might be caused from a split tube. This additional concentration is carried only at the cost of the possibility of priming and the wastage of chemicals. With the introduction of H-ion control a safety factor is introduced which permits a lowering of the alkalinity with perfect safety and a consequent saving in chemicals.

The H-ion control described above is undoubtedly the cheapest method for the systematic control of boiler feed water. In the majority of cases use may be made of existing equipment. The chemical dosage is not merely made proportional to the flow, but also is in such porportion as to roughly compensate for the acidity or the amount of scale forming or corrosive salts present. (This is due to the so-called "buffer" action of these salts.) It is the only method of treatment which will automatically adjust the dosage to compensate for condenser leakage. H-ion control probably requires less attention than any other systematic method of treatment. It also provides a method of preventing corrosion in the preheating sections and feed lines.[15]

It is evident that, if desired, a second chemical such as sodium sulfate or soda ash could be added automatically in a definite ratio to the amount of alkali added. This could be accomplished by means of a second valve operated by the same gear reduction. The control is thus adaptable to practically any type of water treatment which depends for its success upon H-ion concentration.

In conclusion the writers desire to acknowledge their indebtedness to the officials and employees of the Public Service Electric and Gas Company for their hearty coöperation and many suggestions during the perfection of this equipment.

[15] The writers cannot agree with the recommendation of R. E. Hall (Mechanical Engineering, **48**, 321, 1926) for the recirculation of boiler water through the feed water system, in order to accomplish this purpose. Hall recommends a continuous blow off, which recirculates, as a method of obtaining the requisite caustic for the prevention of corrosion without the danger of building up boiler causticity. This method is exactly equivalent (with the possible exception of the saving of a small amount of heat) to a continuous blow off and the continuous addition of a like amount of caustic to the feed system, with an advantage in the latter method in that the salt content of the boiler would be reduced while the causticity remained constant.

SUMMARY

1. Facts have been presented which indicate that control by H-ion measurements is the most logical systematic method of treating boiler feed water.

2. A practical installation of this control has been described and its method of operation explained.

3. The advantages gained have been, the safe reduction in treatment, a more uniform control of alkalinity in the individual boilers, a more uniform control of the average alkalinity of the boilers as a whole, and a reduction in the dicrepancies between the alkalinities of the individual boilers.

4. Control by H-ion measurements is doubtless the cheapest systematic method of treatment, and it requires the least amount of attention.

5. H-ion control of boiler feed water is the only method which automatically compensates for condenser leakage.

6. H-ion control also adds chemicals automatically in proportion to the flow, and in such proportion as to approximately compensate for the acidity or salt content of the feed water.

7. It provides a method for the prevention of corrosion in the preheating sections and the feed lines.

THAWING FROZEN SERVICES WITH ELECTRIC CURRENT

By J. W. McAmis[1]

During the recent cold weather which visited the country during the holidays the writer learned two things regarding the operation of water works that seem to be worth relating. While we had ample warning of a sudden drop in temperature, via radio and newspaper weather reports, probably half the water consumers had trouble with frozen pipes. Living conditions in even the small city residence become almost intolerable when water service is interrupted for more than a few hours, and as the plumbers were hopelessly swamped the situation was really serious by the second day of the cold wave.

The writer had heard vague rumors of thawing frozen pipes with electricity some years past while working in Philadelphia, but he was not fortunate enough to learn how it was done. He began to search through all the literature available to try to discover the secret. The search was finally rewarded by finding a short paragraph in the "Municipal Index" for 1924, page 304, giving the essentials of the method. A call was immediately made on Mr. Davis, local manager for the electric utility, with a view to getting his opinion as to whether the scheme was workable in Greeneville, and whether the proper equipment was obtainable. Mr. Davis was quite taken with the idea, being anxious to render any service to our mutual friends and customers, in their hour of need. We accordingly agreed that we would have this work done at the actual cost, making no charge for anything for which we did not have to pay out the cash.

The Electric Company loaned two ordinary 10 kva. type H service transformers, an oil switch, the necessary wire and fuses, and a lineman whose service was to be paid for at his regular rate of pay. The water works furnished a ½-ton Ford truck at $5.00 per day, a

[1]Superintendent, The Water Commission, Greenville, Tenn.

man who was familiar with the mains, services, etc., with a helper, and this completed the outfit.

Figure 1 shows the method of wiring the transformers, switch and fuses. The ten ampere fuses are a very necessary part, to protect the transformers from possible overload, the switch for cutting off the current. It is best to run the wires direct from the pole to switch, so that a blown fuse may be replaced without climbing the pole. The equipment is securely mounted on the Ford truck, so that it cannot shake about in moving from job to job. It is neces-

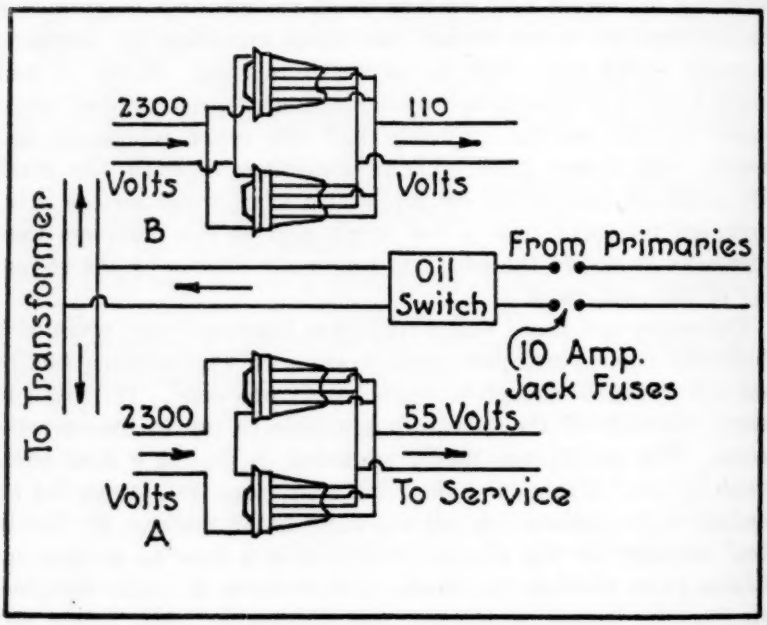

FIG. 1. TRANSFORMER WIRING

sary to make connection to the primary (2300 volt) circuits in order to get sufficient power to warm the pipe. All wires carrying the 2300 volt current should be encased in heavy rubber hose where they are within reach of the workmen, so as to make the arrangement as safe as possible. The secondary current delivered from this arrangement (fig. 1, *A*) is at 55 volts, and the wires carrying it may be handled with ordinary caution and, if the weather-proof insulation is good, it may be strung around almost anywhere on the ground or paving.

The idea is to connect the two wires leading from the secondary side of the transformers to the pipe so that the frozen section will be between two connections and will be part of the circuit. If the section of pipe between the connections is too short, too much current will be delivered and the fuses will blow, and if the section is too long it takes too long to warm the pipe. The amount of pipe included in the circuit may be varied at will by moving one or both the connections so as to include more or less pipe as desired. Our practice of setting the meter at the curb lends itself very well to this, as a connection may always be had at the meter.

A ¾-inch service pipe 150 to 300 feet long, or a ½-inch service 100 to 200 feet may be thawed in five minutes after the connections are made. We thawed a 1-inch service 900 feet long in ten minutes, but the transformers had to be reconnected to give 110 volts (fig. 1, *B*). This may be accomplished by changing the primary connections to the transformers from series to parallel.

It should be remembered that shorter and larger pipes allow more current to flow, and longer and smaller pipes offer more resistance to the flow of the electric current the same as they do to the flow of water.

Whether or not the pipe is warming may be found by holding the hand on some part between the connections. It is better to begin with a long section of pipe at first and shorten as necessary than to try to thaw sections that are too short. The connections may be made to include more pipe by simply connecting to the next service or meter down the street. The most economical speed may be had on this work by using three men, a lineman to connect to the primaries and two water works men to connect at the curb and to the spigot inside the house.

These three were able to do about twenty jobs in a day of eight hours. We estimated that an average of about 10 kilowatt hours were consumed for each job and Mr. Davis charged for the current on that basis. No meter was available for the 55 volt current and the actual power consumption was not determined.

We arranged for the local daily paper to give us enough space to explain about the thawing service and the next day we found ourselves to be two of the most popular members of the community, which was rather a novelty for both Mr. Davis and myself.

STANDARD LENGTHS OF CAST IRON PIPE CAST HORIZONTALLY[1]

By J. R. McWane[2]

So far as we know, the oldest cast iron pipe of which we have any record was cast horizontally. Practically all of the cast iron pipe taken up in the older sections of the country, to be replaced with larger sizes, and exhibited as evidence of the longevity of cast iron pipe, was cast by the horizontal method in green sand.

The horizontal casting of pipe in 12-foot lengths was abandoned many years ago for various reasons. In the first place, the old fashioned method of floor molding was slow and did not lend itself to large production. Excessive quantities of sand were used, the chief requirement for which was a shovel and a strong back. Keeping the core central in the mold was a problem which was usually solved by the use of what is known as a chaplet. Pouring difficulties involved a choice of evils, either a ladle at each end of the flask with a long distance for the iron to run, or a number of ladles with a high labor cost.

To obviate these difficulties, the vertical method of casting in dry sand molds was adopted. Dry sand was specified, because in dropping iron 12 feet a green sand mold will cut, and it is necessary to have a hard baked surface to resist the force of the molten iron. There is no merit in dry sand in itself. On the other hand, the drying of a mold results in slower cooling, with consequent comparative weakness of the casting.

In the early days of vertical casting, the weights of pipe were much lighter than they are now. As production, however, grew, and the labor turnover increased, it became more and more difficult to make the lighter weights by the vertical method, resulting finally in the American Water Works Association Specifications as adopted in 1908, with weights considerably heavier than those formerly specified.

[1] Presented before the Joint Meeting of the Plant Management and Operators and the Fire Protection Divisions, Buffalo Convention, June 9, 1926.

[2] President, McWane Cast Iron Pipe Company, Birmingham, Ala.

In recent years the necessity has arisen for lighter weights. This is due to the increasing cost of pig iron and coke, and the increase in freight rates. When pig iron was selling at $7.00 or $8.00 per ton Birmingham, and railroads were cutting rates and offering rebates, the matter of a few surplus pounds per foot in the weight of cast iron pipe was not serious; but now since the cost of pig iron is three fold and every revision in freight rates is upward, manufacturers are trying to adapt themselves to the changed situation. Moreover, this movement to reduce the quantity of iron going into cast iron pipe is in keeping with the modern tendency to conserve materials in every possible way consistent with safety and service. There is no relation between the thickness and longevity of cast iron pipe. Rust forms a protective coating, and does not flake off. A thin pipe will last as long under ground as a thick one. In fact, the balance is in favor of the thin section on account of its closer grain.

This necessity of revising weights has led to a re-study of the methods of casting. Inasmuch as a thinner pipe section can be cast horizontally than can be made vertically there has been a reconsideration of the horizontal method. It was found that since this process was abandoned many improvements have been made in the art of molding which were not thought of at the time the vertical practice was resorted to. Chief among these improvements are the molding machine, with drop patterns and stripping plates, sand handling and sand cutting machinery, core machines for making green sand cores, multiple lip ladles, and a device for holding core bars central in the mold without the use of a chaplet. This latter development is probably the most important in its bearing on the manufacture of standard 12- or 16-foot lengths of pipe by the horizontal method. Without going into details, it is sufficient to say that this result is obtained by utilizing in a novel way certain well known mechanical principles.

Usually the return to a system that has been discarded for many years is considered reactionary, and this criticism has been made of the horizontal casting of pipe. It must be borne in mind, however, that about the only thing in the modern practice of casting horizontally that resembles the old method is the fact that the molds and the pipe occupy a horizontal rather than a vertical position. The equipment and the practice in general are all entirely different—patterns, flasks, sand handling, ramming, core making, iron pouring—all have been revolutionized.

The horizontal method is the natural way to make cast iron pipe, and in making it this way you are working with, instead of against, nature.

It is natural, first, in dispensing with pits and doing the work on a level floor. Handling heavy equipment in and out of a deep pit is an expensive process, aside from the danger.

The horizontal method is natural, secondly, in the materials used, and the conditioning of these materials. Besides the molten iron, only two materials are required for making cast iron pipe horizontally, molding sand and core sand, tempered with water to about the degree of natural moisture contained when the sand is taken out of the earth. By a system of sand control, the preparation of these materials is reduced to a fine science, with accurate determination of moisture, strength and permeability. Contrast this brief list with the materials used in dry sand vertical casting —molding sand, sharp sand for body cores and for head cores, clay, blacking, glutein or molasses, hay, excelsior or paper for cores, first and second coat for cores made of mud which must be thoroughly dried, excess moisture being put in and then driven out, coke or gas for drying. Surely, getting back to nature gets rid of a lot of complications.

It is natural, thirdly, in the results of casting. In making a thinner section in green sand rather than a thicker section in dry sand, you are again working with, rather than against, nature. In an article in the "Iron Age" of August 7, 1924, on the "Strength of Cast Iron and Its Thickness," by Mr. Willard Rother, of the Buffalo Foundry and Machine Company, Buffalo, N. Y., the writer makes the following statement:

> At the present time some engineers assume that if a certain cast iron has an ultimate strength of 25,000 pounds per square inch, a section of 2 square inches in area should have a total strength of 50,000 pounds, one 3 square inches in area 75,000 pounds, etc. Unfortunately, this is not correct, as the results of the following tests show.

Further on in the article he says:

> The controlling factor governing the strength of cast iron is the presence of graphitic carbon, or carbon in the free state. It is well known that the proportion of free and combined carbon varies with the thickness of a casting. A thin casting cools quickly and allows a considerable portion of the carbon to remain in the combined state, which gives a close-grained iron. The same iron

poured in a heavier section cools much more slowly, permitting increasing quantities of carbon to change from the combined to the free state. In proportion to the time consumed in cooling, the metal becomes coarser and weaker.

The above statement confirms the contention that the thinner a cast iron pipe section is the stronger it is in proportion to its thickness. In other words, nature penalizes you for increasing and rewards you for decreasing the thickness of a cast iron pipe section.

The green sand mold with the green sand core is the natural way of utilizing this principle of cooling for an increase of strength. The hot dry sand mold and core cool the iron too slowly, the permanent mold cools it too rapidly, necessitating superheating or annealing. The moisture in the molds and cores of the green sand seems to be just the proper amount to close the grain of the iron and secure strength, leaving the casting machinable without strains, and with the necessary resiliency to ship well and withstand the shocks to which it is subjected in handling and in service. The green sand process, therefore, is the happy mean between two extremes.

A green sand core is especially efficacious because it leaves a smooth interior and closes the grain on the inner surface of the pipe where strength is needed to take care of bursting strains. Also the core makes it possible to increase the wall thickness at points where it is needed.

It has been found that the hotter iron is when it arrives at its final destination in the mold the stronger the casting will be. This is confirmed by the fact that in testing vertically cast pipe to destruction most breaks occur in the lower half of the pipe. The multiplicity of gates in horizontally cast pipe makes for strength, because in this way the iron is delivered to its final resting place in the mold at the maximum temperature.

Test bars used by the Underwriters' Laboratories and cut from walls of a number of 6-inch pipe cast this way showed an average tensile strength of 29,953 pounds. The average bursting pressure of twenty-nine 6-inch pipe with an average wall thickness of 0.37 inch was 1972 pounds.

The horizontal method is very flexible, making it possible to produce pipe either with or without beads, to vary the design of the bells and to cast plainly any desired numerals or lettering. While flexible, the system lends itsef to standardization, because one in-

ternal and external diameter, one weight per foot, is used for pressures ranging from a few ounces of gas to 150 pounds working pressure of water.

The secret of the longevity of cast iron is its nearness to Mother Nature, representing the first step in the refining process. So the secret of high quality and low cost in the manufacture of cast iron pipe is getting back to nature and developing a system in closest possible harmony with nature's laws. This has been the ideal in the horizontal casting of standard lengths of cast iron pipe.

EARLIER DETERMINATION OF BACTERIUM COLON[1]

By C. J. Lauter[2]

Assuming the presence of Bacterium colon as the index of pollution in water works control and the production of a safe effluent it is extremely important to be able to detect its presence to the highest degree of accuracy and in as short a time as possible. Confirmation on various differentiating media and sugars and study of morphology should by no means be disregarded, but we are all aware that this is a long process and by the time we complete a test, the consumer will have had the water served him two or three days past. This work should be used occasionally to check up other and faster methods of determination which are used in daily routine and in making special investigations or tests.

This paper with accompanying tables is a complete review to date of the research work performed at the Washington, D. C. Filtration Plant laboratory on brilliant green bile medium as originally proposed by Hale of New York, and then studied under the committee headed by McCrady of Montreal. The summary of results of the last years coöperators on this committee was presented to this body by McCrady at the Louisville meeting and appeared in the December, 1925 issue of The Journal.

Not having used a sterilizing agent of any sort prior to 1922, and using liquid chlorine in the filter effluent intermittently since then, it is extremely important that we develop some reaction or find some medium that will give us a few days gain in checking up the quality of the water as it pursues its course through the three preliminary sedimentation and coagulating basins prior to filtration on the slow sand filters.

It has been demonstrated in the past five years that with only the slow sand filters and preliminary coagulation with alum, we cannot give the city a water falling within the Treasury Standard limits. It may be interesting to state here that the percentage of Bacterium

[1] Presented before the Water Purification Division, Buffalo Convention, June 10, 1926.

[2] Chief Chemist, Water Filtration Plant, Washington, D. C.

colon positive in 10 ml. samples runs as high as 35 per cent positive in 10 ml. on a five-tube 10 and 1 ml. dilution on the unchlorinated water.

TABLE 1

Filtered Water

	NUMBER OF SAMPLES	NUMBER OF TUBES	PRESUMPTIVE GAS	COLON EOSIN-METHYLENE BLUE OR ENDO	PER CENT GAS CONFIRMED
Lactose broth (standard methods)					
December, 1923	675		294	118	40
January, 1923	714		492	316	64
February, 1923	603		361	210	58
March, 1923	614		210	89	43
April, 1923	278		81	8	10
Total	2,884	2,884	1,438	(741)	51
Brilliant green bile (Hale)					
December, 1923	675		143	99	69
January, 1923	714		270	193	72
February, 1923	603		217	156	73
March, 1923	614		94	88	94
April, 1923	278		16	6	37
Total	2,884	2,884	(740)	542	73

TABLE 2

Raw water. Same period as in table 1

	NUMBER OF SAMPLES	NUMBER OF TUBES	PRESUMPTIVE GAS	COLON EOSIN-METHYLENE BLUE ENDO	PER CENT GAS CONFIRMED
S.M. lactose broth	114	114	102	(82)	81
Brilliant green bile (Hale)	117	117	(87)	71	82

Brilliant green bile, 5 per cent, straight dehydrated bile.
Brilliant green—10 ml. 1 per cent aqueous solution per liter.

The first tests of brilliant green bile were made in 1923 when we used the dehydrated bile obtained from Hale's laboratory, using a 5 per cent solution with a 1:10,000 brilliant green (10 ml. of a 1 per cent solution) per liter.

TABLE 3

	NUMBER OF SAMPLES	NUMBER OF TUBES	PRESUMPTIVE GAS	PLATE COUNT		CONFIRM LACTOSE	SPORES	COLON CONFIRMED	PER CENT GAS CONFIRMED
				Endo	Eosin-methylene blue				
A. Filtered water. Unchlorinated									
S.M. lactose	111	555							
Gas: 24 hours			24	16	20	18	0	18	75
Gas: 48 hours			178	44	45	67	0	(67)	38
Bile No. 12224	111	555							
Gas: 24 hours			17	8	15	15	0	15	88
Gas: 48 hours			54	24	31	43	0	43	80
Gas: 72 hours			(66)	28	33	46	0	46	70
B. Raw water									
S.M. lactose	121	363							
Gas: 24 hours			146	109	129	142	0	142	97
Gas: 48 hours			290	162	177	220	0	(220)	76
Brilliant green bile No. 12224	121	363							
Gas: 24 hours			123	88	128	113	0	113	91
Gas: 48 hours			208	137	151	186	0	186	88
Gas: 72 hours			(228)	140	153	193	0	193	85
C. Chlorinated water									
S.M. lactose	90	450							
Gas: 24 hours			3	0	2	2	0	2	67
Gas: 48 hours			141	1	3	6	0	(6)	4
Brilliant green bile No. 12224	90	450							
Gas: 24 hours			1	0	1	1	0	1	100
Gas: 48 hours			6	1	2	4	0	4	67
Gas: 72 hours			(6)	1	2	4	0	4	67

Brilliant green bile: 5 per cent solution Difco Ox Gall No. 12224.
Brilliant Green: 10 ml. of 1 per cent sol. per liter. Coleman Bell No. 184.
All tubes of series 11 made using 10 ml. of medium to 10 ml. of water.
Series of 1925–1926.

Table 1 covers the period of the five winter months from December to April, at which time our water is at its worst. It will be noted that on the run only 51 per cent of the tubes giving gas in lactose confirmed on eosin, whereas in bile 73 per cent confirmed. The interesting thing here however is the fact that we have 740 presumptions on bile in two days and 741 confirmatory on lactose, after a minimum of three days, a gain of one day with exactly the same figure, assuming all bile gas as colon. On the raw water we have 87 presumptives in two days against 81 confirmed lactose in three days, a greater number of positives evidently if we take this as our index, but on the safe side. (See table 2.)

The next series of tests were run a little more fully in all respects, that is, the full routine confirmation of all 10 per cent gas; on eosin,

TABLE 4

	NUMBER OF TUBES	LACTOSE GAS	CONFIRMED COLON PLUS
1922–1923	4044	1257	111
1923–1924	4238	1385	306
1924–1925	3517	544	105
Average.....	3966	1062	(174)

	NUMBER OF TUBES	BILE GAS	POSITIVE ON EOSIN	POSITIVE ON M.R.
1925–1926	3690	(166)	162	165

followed by secondary lactose and spore test. Table 3 will bring out these facts.

The percentage of confirmations is higher then with the previous bile due of course to the cutting out of practically all of the anaerobes with which we are bothered and which runs up our gas tubes to these enormous figures. Thus we obtained in two days the same number that we did after four days complete confirmation on lactose.

The 66 presumptives with unchlorinated filtered water on three days bile compare favorably to 67 four-day confirmatives on lactose and the 228 on raw water are close enough to the 220 confirmatives on lactose four days to warrant stopping at the first point, namely the formation of gas in bile.

This gas called positive in all cases was 10 per cent or more in both media. It might also be interesting to note that 10 ml. of medium were used with 10 ml. of water in tables 3A, 3B and 3C.

TABLE 5

	LACTOSE GAS		EOSIN-METHYLENE BLUE POSITIVE		BRILLIANT GREEN BILE POSITIVE		PER CENT CONFIRMED	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
A. Filtered water. 10 ml. 1215 tubes								
July, 1925	1	31	0	1	0	2		
August, 1925	2	23	0	0	1	1		
September, 1925	0	8	0	1	0	1		
October, 1925	1	17	0	2	1	5		
November, 1925	37	86	32	46	34	52		
December, 1925	16	85	14	22	15	28		
January, 1926	6	40	1	6	2	12		
February, 1926	9	42	9	17	9	18		
Total	72	312	57	95	62	119	(L.) 79 (B.) 86	3 3
9.8 per cent of tubes								
B. Filtered water. 1 ml. 1215 tubes								
July, 1925	1	2	1	0	1	0		
August, 1925	0	4	0	0	0	0		
September, 1925	0	0	0	0	0	0		
October, 1925	0	2	0	0	0	0		
November, 1925	3	14	2	7	2	7		
December, 1925	3	9	3	1	3	3		
January, 1926	0	2	0	1	0	1		
February, 1926	1	8	1	2	1	2		
Total	8	41	7	11	7	14	(L.) 87 (B.) 87	26 34
C. Chlorinated water. 10 ml. 1025 tubes								
May, 1925	0	26	0	0	0	0		
June, 1925	1	38	1	1	1	1		
July, 1925	4	38	4	5	4	6		
August, 1925	4	26	3	4	4	5		
September, 1925	0	10	0	0	0	0		
October, 1925	3	24	3	4	3	4		
November, 1925	0	55	0	0	0	0		
December, 1925	0	45	0	0	0	0		
Total	12	262	11	14	12	16	(L.) 92 (B.) 100	
1.17 per cent of tubes positive								

Following these results we have proceeded with the use of brilliant green bile in our work on the 29 filters which are run daily and also on some of the other waters of the preliminary sedimentation basins, also continuing the use of lactose on the composite filter effluent before chlorination to comply with standard methods in case any legal proceedings may arise.

The results of these filter bed samples of filtered water, unchlorinated for fall and winter months, compared favorably with the average for the same period for past three years as confirmed in regular routine on lactose broth and confirmatory plates and tubes.

Table 4 gives the yearly and average tests.

Here, although we have three days bile against two days lactose and confirmation on plate making a total of three days, we do however save a great deal of labor and media and get about the same results, 166 against an average of 174 for similar period.

In addition to the above work we have added another series for study based on last years suggestion for use of brilliant green bile as a confirming medium in place of eosin-methylene blue plates.

Our series was made using the regular Difco Ox Gall, making a 5 per cent bile and 10 ml. of a 1 per cent brilliant green solution per liter using Coleman Bell No. 190. Our eosin-methylene blue was made from its component constituents in our laboratory daily, using Difco products as we do not experience as good results with dehydrated medium which requires longer incubation to produce the characteristic sheen.

The check is very good and in favor of bile giving a greater number positive which means a greater tendency toward safety in watching a water. All doubtful cases on eosin from lactose were run on secondary lactose and slides made of same and in most cases when bile was positive and eosin negative, apparently we got further confirmation on secondary lactose.

In all this time the chlorinated effluent gave plenty of gas positive in lactose, but no confirmation in bile or eosin. It apparently is simpler and easier to make the bile tubes than eosin plates and presence or absence of gas in any desired volume is also easier to note than a color reaction which has proven itself off shade so much of the time.

Naturally there will be some limitations to the use of this medium, but for us and a great many other laboratories it will be a time saver.

THE DIAGNOSTIC VALUE OF NEUTRAL RED LACTOSE PEPTONE MEDIA FOR THE COLI-AEROGENES GROUP[1]

By F. R. Georgia[2] and Rita Morales[3]

A number of early workers in the field of water bacteriology used neutral red in culture media as a means for detecting the presence of members of the colon group in water. These workers followed the custom of their time and, ordinarily, employed dextrose as the sugar in their media. As we now know a large number of organisms ferment dextrose that do not belong to the colon group, and in addition certain of these are able to produce a color change in neutral red. Under such conditions it is only natural that neutral red media should have fallen into disrepute.

It was not until Stokes (1) published his work in 1904 that a medium of real value was proposed. In the first place he used lactose instead of dextrose in his medium thus limiting gas production to the members of the colon group and a comparatively small number of other forms. In the second place he ran his fermentation tests in Smith tubes, and showed that under these conditions Es. coli not only produced gas, but changed the color of the neutral red in the closed arm to a fluorescent canary yellow while the color in the bulb or open arm was unchanged, with a sharp line of demarcation separating the two.

In 1915 and 1917 Chamot (2, 3, 4) and his coworkers published the results of their investigations on neutral red lactose peptone media. Their work was chiefly concerned with the composition of the medium, the amount of gas produced, the gas ratios obtained, and the chemical changes produced in the neutral red.

It did not appear to us that this medium had received the recogni-

[1] Contribution from the Department of Chemistry, Cornell University. The investigation upon which this article is based was supported by a grant from the Heckscher Foundation for the Advancement of Research, established by August Heckscher at Cornell University.

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tion and use to which we felt it was properly entitled. In addition, since this work was published, there has been a growing tendency to differentiate between the different members of the coli-aerogenes group. We decided, therefore, to study in a systematic way the organisms causing fermentation with gas production in this medium when employed in the examination of water samples.

The general plan of the investigation was as follows:

1. Smith tubes containing the neutral red medium were inoculated with water samples.
2. Levine's (5) eosin methylene blue agar was inoculated from tubes showing gas at the end of 24 hours. If gas developed in other tubes in 48 hours they were also subcultured in the same manner.
3. The amount of gas and the color reaction in the fermentation tubes was recorded at the end of 48 hours.
4. Colonies typical for the coli-aerogenes group were picked from the eosin methylene blue agar plates after 24 hours' incubation at 37°C. and planted on nutrient agar slants.
5. The slant cultures were reinoculated into Smith tubes containing the neutral red medium and the amount of gas and the color reaction recorded after 48 hours and, if not typical,[4] again after 72 hours.
6. Two tubes of Clark and Lubs (6) medium were inoculated from the agar slants for methyl red and Voges-Proskauer tests. The methyl red test was made after 5 days' incubation at 37°C., and the Voges-Proskauer test after 3 days' incubation at 37°C.
7. A preparation from the 48 hour slant culture was examined microscopically using a Gram stain.

If the pure cultures obtained by subculturing presumptive fermentation tubes were shown to be Gram-negative, non-sporulating rods, capable of growing aerobically, and giving typical colonies on eosin methylene blue agar, typical contrast color reactions with gas production in neutral red lactose peptone, and proper correlation between the methyl red and Voges-Proskauer tests, they were regarded as typical members of the coli or aerogenes groups. Such cultures were discarded without further study.

Pure cultures that were atypical in one respect or another were kept and studied in greater detail, and if possible the species determined.

[4] By a typical reaction we mean a tube showing gas production with a fluorescent yellow color in the closed arm, a port wine red in the open arm, and a sharp line of demarcation between the two in the stem uniting the closed and open arms.

CULTURE MEDIA EMPLOYED

I. Neutral red lactose peptone:

Peptone (Witte)	30 grams
Lactose	10 grams
KCl	6 grams
Neutral red	0.08 grams
Water to make	1000 cc.

II. Levine's eosin methylene blue agar:

The "Difco" dehydrated product was used quite successfully. The dye concentrations seem to be properly adjusted in this product so that typical colonies are obtained (7).

III. Clark and Lubs medium:

Peptone (Witte)	5 grams
Dextrose	5 grams
K_2HPO_4	5 grams
Water to make	1000 cc.

This medium was used both for the methyl red and Voges-Proskauer tests.

IV. Special sugar media:

Peptone (Witte)	30 grams
KCl	6 grams
Sugar	10 grams
Water to make	1000 cc.

The sugars were sterilized separately in aqueous solutions and added aseptically to the rest of the medium.

V. Nutrient Agar:

The "Difco" dehydrated product was used for most of the work.

The neutral red and special sugar media prepared with Witte peptone as above give reactions rather close to pH = 7.0 and do not need adjustment.

EXPERIMENTAL

A total of 184 samples of water and soil infusions from a wide variety of sources and localities were cultured.

For the purpose of this investigation we have not required that a fermentation tube should show 10 per cent of gas before being regarded as a presumptive test, but have regarded all tubes showing gas as constituting a presumptive test for the coli-aerogenes group. Usually more than one fermentation tube was inoculated from the same sample.

The results may be summarized as follows:

Fermentation tubes confirmed

Typical neutral red reaction, 48 hours		289
Typical neutral red reaction, 72 hours		20
Tubes in which neutral red was completely reduced		73
Tubes in which no reduction took place		22
Total confirmed as members of coli-aerogenes group		404

Fermentation tubes not confirmed

Typical tube from which a M.R.+, V.P.+ culture was isolated		1
Typical tube from which a mixed culture was obtained		1
Typical tubes, 72 hours, but from which on subculture no gas producers were isolated		2
Atypical tubes from which on subculture no gas producers were isolated		16
Tubes which on subculture gave no growth on eosin methylene blue agar:		
Typical tubes but showing only a trace of gas	2	
Atypical tubes showing only a trace of gas	1	
Tubes completely reduced	6	
	9	9
Tubes from which typical colonies were not obtained on eosin methylene blue agar:		
Tubes completely reduced	12	
Tubes showing no reduction	5	
	17	17
Tubes from which no growth was obtained on agar slants:		
Typical tubes and typical colonies on E.M.B. agar	4	
Tubes completely reduced	1	
	5	5
Total presumptive tubes		455
Negative tubes		60
Total tubes inoculated		515
The typical tubes were divided as follows:		
Total number of typical tubes		319
Typical tubes confirmed		309

A mixed culture was obtained from one of the 10 tubes not confirmed and the lactose fermenting organism lost. From another

the culture isolated was methyl red +, Voges-Proskauer + and may have been a mixture of coli and aerogenes forms. Four cultures from typical tubes were lost on transfer to agar slants possibly due to technique. From two typical tubes no growth was obtained on eosin methylene blue agar and from two more no gas producers were obtained from the eosin methylene blue agar. The fermentation in these last four tubes may have been due to anaerobes or symbiotic complexes as pointed out by Sears and Putnam (8), and by Leitsch (9). It is, therefore, probable that the confirmation of 309 out of 319 typical tubes or 96.8 per cent is actually lower than it should have been.

Confirmation was obtained from 73 tubes that were completely reduced. We have isolated from tubes of this sort, in addition to a member of the coli-aerogenes group, organisms capable of completely reducing neutral red. When such organisms are present they will interfere with the production of a typical contrast color reaction.

In the case of 22 tubes confirmation was obtained although reduction was absent. The absence of reduction is probably due to one of two reasons. Some attenuated forms when first isolated fail to reduce neutral red or reduce it rather slowly. Such cultures frequently become normal in this respect after suitable cultivation. In addition certain of the more unusual members of this group that we have isolated do not reduce neutral red or do so quite slowly.

Laboratory cultures obtained from the New York State Department of Health, Professor Max Levine, The American Type Culture Collection, and the Cornell University laboratories were run through as checks on the procedure. These cultures included the following: coli (2 strains), communior (1 strain), grünthali (1 strain), pseudocolloides (1 strain), neopolitana (1 strain), acidi-lactici (1 strain), aerogenes (3 strains), oxytocum (1 strain), cloacae (2 strains).

All of these gave typical reactions in neutral red in 48 hours except one of the aerogenes strains and the culture of oxytocum which required 72 hours, and the two strains of cloacae which were evidently contaminated since they failed to ferment lactose.

Various organisms such as Cl. welchii have been mentioned as giving a contrast reaction in neutral red media. We have failed to obtain such a reaction with welchii even when in mixed cultures, except when grown under anaerobic conditions.

Chamot and Sherwood did not find any inhibition of the members

of the coli-aerogenes group by neutral red in concentrations such as we have employed. In order to further check this point a portion of our neutral red tubes was paralleled by plain lactose peptone tubes in which the media differed only in the omission of the neutral red. The results were as follows:

	WITH NEUTRAL RED	WITHOUT NEUTRAL RED
Total presumptive tubes	56	60
Total tubes confirmed	49	43
Presumptive tubes not confirmed	7	17
Negative tubes	41	37
Total tubes inoculated	97	97

Of the 49 neutral red tubes completely confirmed 40 gave typical reactions while 9 were atypical. Of the 7 presumptives that were not confirmed only 1 was typical, the remaining 6 being atypical.

A sufficient number of tubes was not run from which to draw definite conclusions but the results do serve to bear out the results of Chamot and Sherwood. Tubes were regarded as presumptive if they showed any amount of gas in 48 hours.

During the course of this investigation various observations were made that do not deal directly with the neutral red medium but which are perhaps worth recording.

Confirmation was obtained on a total of 447 neutral red and plain lactose peptone tubes. These may be grouped by means of the methyl red and Voges-Proskauer reactions as follows:

Coli section	325
Aerogenes section	48
Members of both coli and aerogenes sections	74
Total	447

Including the 11 laboratory strains studied we have obtained complete correlation between the methyl red and Voges-Proskauer tests on a total of 532 cultures of which 406 belonged to the coli section and 126 to the aerogenes section. At the beginning of our work we followed the plan of using tubes of Clark and Lubs medium incubated for 5 days at 37.5°C. and using aliquots of these for the two tests. With this procedure we were unable to obtain correlation

between the tests in several instances. Linton (10) has recently shown that a 5 day incubation period frequently results in a negative Voges-Proskauer reaction. We adopted, therefore, the practice of inoculating two tubes of Clark and Lubs medium and incubated one 5 days for the methyl red test and the other 3 days for the Voges-Proskauer reaction. With this procedure we were able to obtain the complete correlation on the 532 cultures mentioned above. It should be noted also that in the case of 5 cultures belonging to the coli section that methyl red − reactions were at first obtained. These all became methyl red + when rechecked.

In addition to the above cultures one other was obtained that was methyl red +, Voges-Proskauer +. It is possible, however, that this culture was not pure.

Our experience with Levine's eosin-methylene-blue agar was rather similar to that reported by Howard and Thompson (11). In general it was possible to distinguish coli and aerogenes types on this media. In a number of instances, however, colonies were picked for one type and proved to be the other. As in the work of Howard and Thompson we also picked some colonies that appeared to be typical but which failed to ferment lactose.

In the course of the work outlined above whenever a pure culture of a member of the coli-aerogenes group was isolated, which did not give a typical reaction in the neutral red medium or which gave a retarded reaction, this culture was studied further and the species determined according to Bergey's Manual of Determinative Bacteriology (12) whenever possible. A total of 104 cultures was accumulated in this manner of which 40 belonged to the coli group and 64 to the aerogenes group.

Twenty-five of the coli group organisms were indentified as follows:

Es. coli	4
Es. paragrünthali	6
Es. anata	2
Es. grünthali	6
Es. vesiculosa	4
Es. pseudocoloides	1
Es. gastrica	2

Of these 5 became typical in 48 hours after being carried along daily in a favorable medium, 13 were typical at the end of 72 hours, and the remaining 7 were not able to reduce neutral red.

The 15 remaining cultures could not be definitely identified They are tentatively classified below:

Es. coli:	
a. Motility not demonstrated	3
b. Gelatine liquefied	1
Es. paragrünthali: Motility not demonstrated	6
Es. neopolitana: Dulcitol not fermented	2
Es. communior:	
a. Salicin not fermented	2
b. Salicin not fermented, gelatine liquefied	1

Of these cultures 1 gave a typical neutral red reaction in 48 hours, 9 were typical in 72 hours and 5 were unable to reduce neutral red.

Six of the 64 aerogenes group cultures were identified as follows:

Aerobacter aerogenes	3
Aerobacter oxytocum	2
Aerobacter cloacae	1

Of these 3 gave typical neutral red reactions in 48 hours, 1 in 72 hours, and 2 failed to reduce neutral red.

The remaining 58 cultures of this group could not be definitely classified but are tentatively classified below:

Aerobacter cloacae:	
Dulcitol fermented	2
Adonitol fermented	1
Gelatine liquefaction not demonstrated:	
Motile	37
Motility not demonstrated	3
Dulcitol fermented:	
Motile	2
Motility not demonstrated	3
Adonitol fermented	7
Dulcitol and Adonitol fermented	1
Aerobacter levans:	
Gelatine liquefaction not demonstrated	2

Gelatine liquefaction was determined at 37°C. using a maximum period of 10 days.

Of these cultures 11 were typical in neutral red medium in 48 hours, 20 in 72 hours, and 27 failed to reduce neutral red.

It should be noted that a much higher proportion of cultures giving atypical reactions in neutral red medium, was found among

the members of the aerogenes section than in the coli section, and all but 7 of the 64 of the members of the aerogenes section are to be ascribed to the cloacae group.

Of the organisms in the cloacae section we found 7 that fermented dulcitol, 8 that fermented adonitol and 1 that fermented both of these alcohols. Levine and Linton (13) have also reported such types of organisms. Such strains do not find a place in the classification in Bergey's Manual. We do not call attention to this fact with the idea of suggesting further subdivision of the group.

No studies were made of gas ratios, but observations on total gas volumes were made at the end of 48 hours. The results for the pure cultures picked from the eosin methylene blue agar plates may be summarized as follows:

	per cent
Coli section:	
Minimum	5.0
Maximum	80.0
Average for 486 cultures	43.4
Aerogenes section:	
Minimum	15.0
Maximum	85.0
Average for 137 cultures	65.1

The results for gas volumes obtained on the original neutral red fermentation tubes were as follows:

	per cent
Tubes from which only coli members were isolated:	
Minimum	5.0
Maximum	90.0
Average for 294 tubes	45.9
Tubes from which only aerogenes members were isolated:	
Minimum	5.0
Maximum	80.0
Average for 41 tubes	46.1
Tubes from which coli and aerogenes members were isolated:	
Minimum	20.0
Maximum	75.0
Average for 72 tubes	48.9

It is highly probable that a part of the tubes from which only coli or aerogenes members were isolated did in fact contain members of the other section.

The gas volume results obtained on pure cultures showed average

values that were well separated for the two sections of the colon group. The variation in individual cases was so great, however, as to make such determinations of doubtful diagnostic value.

In the case of the original fermentation tubes no well defined differences in gas volumes were obtained for the coli and aerogenes sections. This is probably to be accounted for because of the fact that in such cases we are always dealing with mixed cultures, which may contain members of both sections, and in addition the organisms are frequently attenuated.

SUMMARY

Using the neutral red lactose peptone medium proposed by Stokes and developed by Chamot and Sherwood, in a considerable number of tests, on samples from a variety of sources, we have found that 96.8 per cent of the tubes showing a typical reaction confirmed as containing members of the coli-aerogenes group.

Of all of the tubes that were confirmed 76.5 per cent gave typical reactions; 18.1 per cent were completely reduced; and 5.4 per cent showed no reduction.

Complete reduction may be caused by certain organisms and when present with members of the coli-aerogenes group prevent the typical contrast reactions being obtained.

Absence of any reduction may be due to attenuated forms or to the presence of certain of the more unusual members of the coli-aerogenes group that do not have the ability to reduce neutral red or which do so very slowly.

The medium does not inhibit weak forms and gives as large a number of confirmations as plain lactose peptone media.

Members of both the coli and aerogenes sections of the group give the contrast color reaction in the neutral red medium and cannot therefore be differentiated in this manner. It should be noted, however, that atypical color reactions are obtained most frequently with members of the aerogenes section and especially with members of the cloacae group.

When dealing with pure cultures members of the aerogenes section in general give a considerably greater gas volume than members of the coli section. This difference is not constant enough to be of diagnostic value. This is especially true when dealing with original fermentation tubes that always contain mixed cultures.

As a presumptive medium for the coli-aerogenes group we believe that the neutral red medium is better than anything so far proposed. Our experience with it would seem to indicate that when a typical contrast reaction is obtained further confirmation is unnecessary.

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THE UTILITY CUSTOMER[1]

By G. C. Staley[2]

In speaking of the users of utility service, it is very natural to term them consumers. However proper it may seem to speak of them as such, it seems that they are not merely consumers but are by right, real customers. Webster defines a customer as one who buys regularly from a store or a tradesman, and while a public utility may not be classed as a store or a tradesman, yet the consumer is a regular buyer and under this assumption he is a customer and entitled to all the consideration, courtesy and service which he would naturally expect to receive, and which would be gladly extended to him by the up to date merchant or tradesman.

In looking over the accounts of the utility customers, we find them generally divided into two groups—Industrial and Commercial. There is another division, which ordinarily is not mentioned, and which comprises customers from both the industrial and commercial. This division is made up of small stores, shops and the smaller manufacturing plants, and, while not producing a great amount of revenue, they are an important class of customers in themselves, due to their numbers, and also due to the fact that shop keepers and small merchants and manufacturing plants are in closer touch with neighborhood opinion than the industrial customer.

In looking over the industrial list, we find such customers as public utilities, large manufacturng plants, such as automobile factories, foundries, furniture factories, pharmaceutical manufacturing plants, and others who use a large volume of service. The commercial customers are the residences, apartment buildings, stores, public schools, churches and others who may not use a large amount of service, but whose demands are steady.

The amount of service required by an individual customer varies to a marked degree. This variation may be attributed to a number of reasons. For instance, take two similar automobile manufac-

[1] Presented before the Indiana Section meeting, March 25, 1926.

[2] Cheif Bookkeeper, Indianapolis Water Company, Indianapolis, Ind.

turing plants, both located in the same city, with working conditions and demand for water practically the same. It may be found that one plant is using, and demanding, many times the amount used by the other, and, upon investigation, it will be found that the plant using the smallest amount of water will have, in addition to its public water supply, private wells and its own pumping equipment. Underground leaks and general wastage of water are also factors to be considered in an industrial supply.

In dealing with the industrial customer, who maintains an auxiliary service such as deep wells, there are many times when utility officials can and should coöperate with the industry in the use of its auxiliary system. Whenever there exists a dual system of water supply, special attention must be given in order to safeguard the city's supply of pure water from a possible contamination. In such instances, the close coöperation of the water works officials and the customer becomes a public affair. The following notice was recently mailed to every customer of the Indianapolis Water Company and produced much favorable comment.

A PUBLIC WATER SUPPLY OF HIGH STANDARD

Twenty-two years ago this Company established its laboratory for the control of the safety of the city's water supply, and since that time it has been continuously under the direction of Mr. Harry E. Jordan.

From the beginning this control was a daily affair, and not a random or occasional performance. Samples are collected every day from throughout the distribution system and observations are made hourly at the purification plant. During 1924, 12,000 samples passed the scrutiny of the laboratory staff.

In 1925 the United States Public Health Service adopted a new and higher standard of safety and purity for public water supplies. The laboratory records show that the Indianapolis water supply has for over five years more than met this new and higher standard.

The citizens of Indianapolis may rest assured that their water supply will be held as safe as every bit of modern knowledge and skill can make it.

Indianapolis Water Company,
Indianapolis, Indiana.

I wish to emphasize the fact that, although a majority of the business between the utility and the industrial users is carried on by means of letter and telephone, the company should never lose sight of the value of personal contact and the feeling of friendship and helpfulness should be fostered on all occasions.

UTILITY SERVICE TO THE COMMERCIAL USER

The commercial user is not a large user of service, his demand being steady with very little variation on account of business depressions or other conditions which might seriously affect the business of large concerns. We find that business dealings with the commercial customer are transacted generally by contact in the utility office.

The commercial customer comes to the utility office to have the service connected and also to learn the manner of using this service. There is always the first visit to have the water turned on, and the treatment received by the customer in the office of the utility company leaves a lasting impression. If the customer is treated courteously, and the service explained to him in a perfectly frank and friendly manner by the clerk with whom he is dealing, he will have a friendly feeling for the utility which will not be quickly set aside.

In a great many cases the customer, especially when he wants service connected at a residence or small store or shop, will first call the office of the utility, ascertain the location of the office, if he happens to be a new comer to the city; ask the manner of paying bills and what advance payment or deposit is necessary in order to get the service connected. These questions are usually received by a telephone operator, sometimes being answered by the operator herself, other times being turned over to a telephone or contract clerk, who gives the desired information. If the information is given in a friendly manner and a pleasant voice, the customer feels that already he has established a line of common interest between himself and the utility, and that due to this common interest he has no hesitancy in coming to the utility office, mentioning the fact of his telephone conversation and asking what is further necessary to have service connected.

We now come to the important question of counter and telephone clerks. The use of women clerks at the public windows of a utility has been tried with varying success, but, in our case, we find that the customer prefers to deal with a man clerk instead of a woman, but if the customer is asked his reason for this, in a majority of cases he is unable to give a sound reason for his preference. It seems to be assumed by the customer who is desiring service, that if he can talk to some man, who apparently has the authority to order something done, that service will be given quicker and with more of a

degree of assurance. Before leaving this question we wish to say that many public utilities are employing women cashiers and what today may seem to be an innovation or fad, may tomorrow be found to be a sound business principle.

It is well to refer briefly to the qualifications of clerks placed at the windows for dealing with the public. These men should be of mature judgment, not necessarily old, with at least a high school education, and if possible should be college graduates. This clerk should be naturally adapted to this kind of work—one who is pleasing and friendly in his manner, who has a pleasant voice and yet can speak with a tone of certainty, and who shows by his actions that he is thoroughly familiar with the work he is trying to do. His personal appearance must be above reproach, and inasmuch as it is necessary that the window clerks do a certain amount of writing, figuring and calculating in the presence of the customer, he should be at least a fair penman and accurate in calculations.

It is also well to refer to the qualifications and duties of the telephone operator, for through the telephone, which is today one of the most important connections between individuals, we find that impressions are made, and whether good or bad, are retained, sometimes to the detriment of those concerned. Generally speaking, it is advisable to use a woman in this position, inasmuch as telephone companies, without exception, use women and girls as exchange operators and it is only natural when a customer calls for a public utility office, which is equipped with a private switchboard, to expect to hear a lady's voice at the other end of the line. As I have said before, the first word spoken by the operator creates the first impression the customer has of the utility.

No one having imperfect hearing should be employed in this position, for there is nothing more exasperating to a prospective customer than to have to repeat several times because the operator cannot understand what the customer is saying. The telephone operator must have a world of patience, because when the signal light shows on her switchboard she has no way of knowing whether the call is going to be one requesting information, or an irate customer with real or fancied wrongs, who is bent upon upturning all civilization in order to secure what he thinks are his rights.

It is necessary that the telephone operator have knowledge of all of the duties of the different departments, and it is advisable that she know the personnel of each department, for in this way the

different calls that come in can be transferred to the proper party without the inconvenience to the patron of shifting from one phone to another. Not all women, even though endowed with a pleasant voice, perfect hearing and patience, can become telephone switchboard operators. There is a peculiar adaptability of some women to this work, and when an operator is found who has these peculiar characteristics, a valuable asset is added which cannot be measured by her position on the salary roll.

In rendering a public service, it does not seem possible to satisfy everyone all the time. New equipment and machinery must be added to keep up with the constantly changing demands; personnel and office routine change. What was a satisfactory service last year brings a complaint and criticism this year. In our endeavor to remove the causes for these complaints and criticisms we are giving a more satisfactory service. Complaints made today are welcome, for we try to make of them stepping stones to improve the service of tomorrow.

Most complaints are made in good faith. Others in the hope of having bills reduced, and in some cases, there is no apparent reason or cause for complaint.

We will first take up the causes of the usual inquiry or complaint. These causes may be few or many, and they may or may not be the fault of the utility company. In a majority of cases we believe that it will be found that the inquiry is the result of a lack of knowledge on the part of the customer properly to utilize the service at hand. Poor water pressure; discolored water; high water bills; complaints made because some neighbor is receiving service on a flat rate basis lower than some one else, or the complaint's bill may be higher than his neighbor's bill. All these, and many more, constitute the complaints and questions that must be settled diplomatically and to the best interests of the utility.

When the meter reader takes the reading of the meter and finds the consumption above the usual amount, he makes inquiry of some one at the premises as to any unusual use of water during the preceding month. If no reason for the increase is known, the meter reader at once makes an inspection of the fixtures and in practically all cases the trouble is found and the cause for complaint eliminated. The meter reader reports all such cases to the office and a postal notice is mailed that day to the customer, as follows:

INDIANAPOLIS WATER COMPANY

Indianapolis, Ind.....192 .

To the consumer:

Our meter reader reports that the meter located at.....
.....registers.....cubic feet
for the period.....to.....
This is higher than the usual consumption and may be caused by defective plumbing, leaks or carelessness.

The probable cause of the high consumption as reported by the meter reader is.....

We would suggest that you investigate this matter.

Yours very truly

F. C. JORDAN,
Secretary.

During the month of January over 300 of these voluntary inspections were made by meter readers. In case the customer reports that his service is suspended, or cut off, immediate action should be taken to locate the trouble and apply whatever remedies are customary, and so notify the customer with a minimum amount of delay. When the customer comes into the office of the utility with a complaint, there should be a willingness shown on the part of the person to whom the complaint is made immediately to ascertain the justness of it. If it is found to be based on facts, and there is a justification, it should be speedily remedied. Any credit for overcharge should be immediately adjusted, and if payment has been made cash refund should be made. If, however, the complaint is found to be only fancied, the greatest tact and skill will be required on the part of the clerk in satisfying the customer.

It should not be thought that a complaining customer is a necessary evil, as it is only in this way that the shortcomings and deficiencies of service will be brought to light.

The company should keep a record of all complaints, the cause of the complaint and what was done to remedy the situation. In this way, a better and more satisfactory service can be furnished. To the customer who makes a complaint, it is very often a means of acquiring knowledge, and in the majority of the cases the customer profits to the extent that he does not again find it necessary to make the same complaint.

OFFICE ARRANGEMENT FOR THE CONVENIENCE OF THE CUSTOMER

The majority of modern and up-to-date business establishments such as stores, public offices, waiting stations, and other similar

places, where it is necessary for the public to congregate for business purposes, have gone to a great expense for the comfort and convenience of their customers. Rest rooms, lounging chairs, writing desks and telephones have been installed for the convenience of the customer, and for the same reason that these conveniences were installed for the customer of a retail store, the public utility should arrange its office for the convenience of those who come into the office for the purpose of transacting business.

Unused space in the office lobby may be used to good advantage for educational and advertising purposes. In our office at Indianapolis we have approximately 1000 square feet of lobby space. This space has been utilized with the following exhibits. An aquarium containing gold fish, growing moss and shells; two lavatories, one of the old unsanitary kind with leaking faucets and the other a new and attractive type; an attractive and sanitary drinking fountain; three display meters, all properly connected up and one actually in service; one complete bath room outfit, consisting of shower, tub, lavatory and water closet. At appropriate places in the lobby we have on display large photographs of the pumping stations and equipment.

These exhibits are change frequently and each month the customer who comes to the office will find something new.

We have a bulletin board placed in a conspicuous place, on which are posted items of interest to the customer, such as data relating to metered service, leaking fixtures, reports and comments of public service commissions, etc.

The utility office consists of two main departments. The Cashier's Department, for the payment of bills, and the Service Contract Department for making contracts for utility service and the furnishing of a medium of communication between the public and utility. The public windows should be located at the most convenient place in the office, making it unnecessary for the customer to climb a long flight of stairs, or use an elevator, for the purpose of getting to the proper room to pay bill or make a contract for service. The windows should be plainly marked so that any one entering the lobby of the office may see at a glance the different departments and make it unnecessary to inquire of some one as to which window they should go to pay their bill. There should always be an adequate number of windows to care for the people coming into the

office, and each window should be manned by a sufficient number of clerks.

We find that of the number of individual customers handled in one utility office, the cashier's window handles many, many times the number of those handled by the aggregate of all other windows. This may be explained by the fact that a large number of people prefer to call at the office and pay their bill and receive a receipt. The cashier and his assistants should be equipped with automatic money-changers, cash registers and receipting devices in order that they make the change quickly and correctly that the lines of waiting customers may be served as soon as possible. Politeness, accuracy and speed are three of the most important of the qualifications of a utility cashier. In a number of cases, we find that bills for water service are all made payable on the same day of the month or quarter. This arrangement causes a great confusion and congestion in the office around this paying date.

We have overcome this by a spread of the paying dates over the entire month. About 1500 bills are mailed out each working day. This eliminates the big days and has proven to be one of the most important factors of service for our customers. On our busiest days, a customer may come into the office and pay his bill in less than four minutes time.

CONTRACT WINDOW SERVICE

Service given at the contract windows is equally as important as that of the cashier's window. The contract clerk must be thoroughly trained in his duties and have a natural ability to please the general public, and, at this point, I want to say again, that this position calls for the exercise of unusual diplomatic ability. The public coming into the office forms an opinion of the utility, not by what it afterwards receives, and not by the size of the building, but from the actual reception accorded it by the representatives who stand back of the contract and service windows.

We believe that, while all clerks should be thoroughly efficient and capable of answering any and all question that may arise in the nature of their duties, there are certain lines that should be divided and assigned to different locations.

It seems advisable to have a window where duplicate bills may be secured; one window should be alotted to new service accounts and transfers, and, where plumbers are required to take out permits

making reports on all connections and disconnections made, we find it very advisable that they be waited on at a window entirely removed from that of the general public, as their business is in no way connected with that of service to the public in general. There are arguments for both sides of this question, and excellent reasons may be given for a combination of duties at one or two large windows, or for the separation of the duties to different windows. We believe that with a division of work to the windows where it may be handled by a special clerk in this department, greater efficiency and more direct service to the individual may be given.

It is advisable in all public utility offices to have a floor man, or information clerk, located at a desk in the lobby, which desk may be seen at once by the customer upon entering the door. This information clerk, in case it is a man, should be neatly uniformed and of sufficient intelligence as to the business of the company to answer all ordinary questions pertaining to the service rendered. Care should be used in picking the type of man for this work. It is generally advisable to procure an older person, who has been with the company for some time and who is thoroughly familiar with the different duties of the different departments, as in this way a quicker service and better satisfaction can be given to the customer upon his first visit to the office.

The service bill is the all important factor in the relationship between the customer and the utility company, for it is through the bill that the customer's interest is drawn to the company once every month, or quarter, as the case may be. In the payment of these bills the attention of the customer is drawn directly to the company, and upon the receipt of the payment of these bills the very existence of the company depends. So, what could be more natural than the judging of a utility by the bill rendered. Bills for utility service should always be rendered in a prompt and business-like manner. In some instances the utility companies have their own carriers to deliver the bills; others turn them over to distributing agencies for delivery; in some cases, bills are delivered by the meter readers, but we find that quite a large majority are delivered by the medium of the United States Mail. It has been found, by an actual checking of the cost of delivery by distributing firms, to be approximately 2 cents per bill. This is about the same as the cost of delivery by mail under our present postal rates. After trying out the delivery of bills by distributing agencies and our own carriers, we have returned

to the plan of delivery by United States Mail, which we find to be the most satisfactory plan. There is a difference of opinion, and incidentally quite a difference in cost of delivery, as to the form of bill used. If the bill is made out on a United States Government postal card, it may be mailed for one cent. While, if made on any other form except the Government card, 2 cents is required for the delivery of the bill. If use is made of the Government postal card, it sometimes becomes necessary to eliminate certain essential parts of the bill, or to condense them in such a manner as to lose their effectiveness for clearness to the customer. As it is necessary that the bill be made out accurately as to date and amount, and in cases where the service sold is by meter measurement, it is necessary that the dates of meter readings, together with the readings and the consumption as shown on the meter, be shown upon the bills. We do not believe that it is advisable, where a sliding scale is used consisting of many different steps, to attempt to show the complete manner of figuring the bill through the different steps and calculations. All customers who desire it should be furnished with a schedule showing the entire rate, and, if they so desire, should be instructed how to apply the rate against the total consumption, as shown on their bills. With the proper education of the general public along this line, we believe that very little, if any, complaint will be made from this course.

METER READERS AND INSPECTORS

Meter readers and inspectors are the field representatives of the company. These men in the course of their duties come in contact at some time during the month or quarter with every customer using the utility service. When the meter reader enters the premises of the customer, he is not regarded by the customer as merely a meter reader, but is the direct representative of the utility company who has presented himself for the purpose of transacting a certain important business necessary between the user of the service and the company which furnishes it.

The identification of the meter reader and inspector must be made positive and unmistakable. There is no better way to accomplish this than that of a distinctive uniform which these men should be required to wear while on duty. By the use of uniforms, the customer is protected against impostors; the meter reader reads more

meters because of quick recognition, and the company profits to no small degree through this investment.

The knowledge of a public utility and its employes is gained in a great number of cases only through the contact with the meter readers and inspectors. The meter is read; in a few days a bill comes in by mail; a check is attached to the bill and is returned to the utility office and, unless special occasion requires, it is taken for granted that the transaction is finished and that another period of time will elapse before any more thought is given to a service which stands at the instant command of the utility user.

In the same manner the clerks in the office are the main point of contact between those customers coming to the office to transact their business and the utility, so are the meter readers and inspectors the main point of contact between a larger number of customers and the public utility. If the meter reader shows by his manner and dress that he is a real gentlemen and that he is thoroughly conversant with his duties. If he is courteous, his clothes neat and clean; if he has at heart the duty of service to the customer as well as faithfully serving his employer, there need be no fear but that public opinion, which governs the prosperity of all utilities and business in general, will be found on the right side of the utility when occasion requires.

PROMOTION OF MUNICIPAL BOND ISSUES[1]

By W. R. Gelston[2]

The printed water works literature contains little information which can be used as a guide in setting up and carrying on a campaign for the sale of a bond issue. Perhaps it would be impossible to formulate any guide which would be applicable in all parts of the country, on account of variations in the laws governing the sale of municipal bonds in the different states.

The successful promotion of a bond issue in one Illinois city should, nevertheless, furnish some helpful suggestions for those who have municipal water works improvements to finance in other Illinois cities. This paper will merely review the history of the promotion and sale of the bond issue for the improvement of the 18-million gallon storage reservoir at Quincy.

The Citizens' Water Works Company which operated the Quincy water works plant from 1904 to 1916 was preparing plans for a concrete lining in the reservoir and a concrete roof over it when the proposed improvement was interrupted by the purchase of the property by the city in 1916. The city appointed a Board of three Water Works Commissioners and gave them control of the property and made them responsible for its operation subject to certain restrictions.

The first Commissioners were optimists. They confidently expected to set aside sufficient money from the earnings to do the job within three or four years, but conditions brought about by the war soon doubled the cost of construction work and increased the operating cost and the surplus earnings did not accumulate as rapidly as anticipated. Then the city became financially embarrassed and began using the surplus earnings of the water department for the payment of operating expenses in other departments, and even stripped the plant of $100,000 which had been set aside in a depreciation reserve or sinking fund. The Water Works Com-

[1] Presented before the Illinois Section meeting, March 24, 1926.

[2] Superintendent, Water Works Commission, Quincy, Ill.

missioners finally decided that the reservoir improvement could only be accomplished by means of a bond issue.

The State of Illinois requires the submission to the voters of a proposition to sell an issue of new municipal bonds. The Commissioners, therefore, asked the City Council late in the year 1923 to submit to the voters at the regular city election in April 1924 a proposal to sell a reservoir improvement bond issue. Most of the aldermen were of the opinion that the proposition would be defeated by a large majority and that the cost of such election would be a needless waste of money.

The Commissioners did not insist upon proceeding with the election, but turned their attention, during the following year, to creating a favorable sentiment toward the proposition in the Council. In December 1924 the request for submission of the proposition to the voters was repeated and rather reluctantly granted by the Council. The attitude of several aldermen toward the proposition was that the voters might as well kill it forever in 1925 as later.

In the meantime the Commissioners, two of whom are bankers, had consulted with Chicago banks concerning the bond market, best rate of interest, etc. and one of them, the Harris Trust and Savings Bank, sent a man from its bond department to Quincy to look the town over and get data on its financial standing and to offer the services of the bank to the city.

For a certain consideration the bank agreed to prepare all of the necessary ordinances, papers and proceedings to be prepared and taken by the City Council, including notices, minutes, form of ballot, etc. to make the bond issue legal in all respects and to furnish a favorable opinion covering the legality of all the proceedings by a well known Chicago law firm specializing in bond reports. The bank's proposition also included the lithographing and printing of the bonds ready for the signatures of the proper officials. With the approval of the Mayor and Corporation Counsel the proposal of the Harris Trust and Savings Bank was accepted. The bank then furnished the Water Works Commissioners the following suggestions which were prepared by the lawyers who finally wrote the opinion on the legality of all the proceedings.

1. In order to complete the record in regard to the organization of said City of Quincy and laws governing same, there should be submitted a certificate by the City Clerk confirming our understanding that the city is organized and operating under the general law and that it has not adopted the Commission

Form of Government Law, further, that it has not adopted the Election Commission Act. This certificate should also set forth the names of the members of the City Council and Mayor.

2. That there be supplied a certificate by the City Treasurer revealing the total indebtedness of said City incurred for all purposes.

3. That there be supplied certificate by the County Clerk of Adams County showing the assessed valuation of taxable property in said city as last determined. This should be the valuation as fixed for the year 1924.

4. That ordinance, form of which is enclosed, authorizing these bonds, prescribing the form, and making provision for the levy of taxes to pay same, be adopted at a properly convened meeting of the City Council, and a certified transcript of the proceedings had in that connection supplied. Such transcript should show the convening of the meeting, members present, putting and seconding of pertinent motions, aye and nay votes cast, and declaration of result, and in his certificate the City Clerk should identify a copy of said ordinance either appearing therein or attached thereto as a true and complete copy of same as adopted. His certificate should also affirmatively show that, after its adoption, the ordinance was filed in his office and that the same has been approved by the Mayor.

5. After the ordinance has been so adopted and approved same should be published in a newspaper which is published in said city, and a certificate of publication submitted having attached thereto a copy of the ordinance cut from the columns of the newspaper wherein it appeared.

6. After the adoption of said bond ordinance, another ordinance, ordinance form of which is enclosed, providing for submitting said bond ordinance at the regular City Election to be held on April 7, 1925, should be adopted and a certified transcript of the proceedings had in that connection supplied. In compiling this transcript, observe the suggestions set forth in Paragraph 4 above.

Before this ordinance is adopted all blanks should be properly filled. This ordinance is not required to be published.

7. That notice of the submission of said ordinance, form for which is set out in the ordinance providing therefore, be published in a newspaper which is published in said city, at least once, such publication to be made not less than twenty days prior to the date of said election.

Said published notice must contain a copy of the bond ordinance a list of voting precincts, and respective polling places therefore.

Copy of said notice as so completed should also be posted at each of the polling places, such posting to be made not less than twenty days prior to the date of said election. After notices are so posted there should be submitted a certificate, by the City Clerk, showing where and when such posting was made and having attached thereto a copy of the notice as posted.

8. Form of ballot to be used to vote upon said ordinance is set out in the ordinance providing for the election, and in printing the ballots care should be observed that this form is followed and that the necessary data is printed upon the back of the ballots. The ballots to be used in each of the polling places and voting precincts, on the back thereof will indicate the voting precinct and the polling place.

Bear in mind that the ballot upon this proposition must be separate from ballot used for voting for candidates.

9. After the election has been held, returns thereof should be filed by the election officials with the City Clerk and at a properly convened meeting, the City Council, should proceed to canvass the result of the vote and by ordinance adopted determine the result of the election upon the question of approving said ordinance, and we should be supplied with a certified transcript of such proceedings including a copy of such finding.

10. If the election results favorably for the issue of said bonds, a copy of the bond ordinance certified by the City Clerk should then be filed in the office of the Clerk of said county, and certificate submitted showing such filing to have been made.

Upon receipt of the foregoing information and finding same satisfactory, we will advise what further steps are proper to be taken.

After securing the consent of the Council to submit the question to the voters, the Commissioners contracted with the two daily newspapers for one thousand inches of advertising space in each. This space was used for the publication of educational bulletins. Two bulletins were run each week in both of the papers right up to the day before the election.

These bulletins were not written by newspaper ad writers. They were all written by water engineers and board of health men. Credit should be given here to Messrs. Dabney H. Maury, Paul Hansen and Harry F. Ferguson of this section and to Col. Wm. B. Wrightson, who was Health Commissioner of the Quincy Public Health District for writing six of the bulletins, which were especially effective. Also to Mr. Carl Lauter, chief chemist of the Water Department Filtration Plant at Washington, D. C. for bacterial data on two open and one closed reservoir in Washington.

On election day the bond issue won by a handsome majority, but the entire campaign was almost wrecked by the carelessness of the election officials in three voting precincts. Thirty-one precincts reported 7387 votes for the proposition and 5616 against, giving it a majority of 1771. The other three precincts, in which the total number of ballots cast for city officials was only 1147, made no reports on the vote on the bond issue. If all of the voters casting ballots in these three precincts had voted against the bond issue it still would have had a majority of 621. Nevertheless, the attorneys who were to write the opinion on the legality of the bond issue insisted on having the vote cast in the three missing voting precincts before approving the legality of the election.

Nearly three weeks of valuable time was lost in getting the required information from these three precincts. During this time the election officials, who were responsible for the failure to report, were strangely silent, probably due to a fear that they could be punished for failure to perform their duty under the election law. It was finally definitely established that the votes on the bond issue had been counted in all of the three precincts, but had not been recorded in the poll books on account of carelessness on the part of the clerks of election. The total vote, including the three precincts, was 7950 for and 6061 against, or a majority of 1889 votes for the proposition.

This vote gave the City officials authority to sell bonds in the sum of $250,000, maturing serially from the year 1926 to 1940, both years inclusive and bearing interest at the rate of 4½ per cent, payable semi-annually. On account of the unexpected delay in getting the complete election returns, the bonds could not be sold until after the date fixed for opening the bids on the proposed construction work. These bids were opened on May 28. The bids were lower than anticipated, the low bid being approximately $175,000 and the Water Works Commissioners decided that the amount of the bonds to be sold might well be reduced. The amount to be sold was fixed at $205,000.

Nineteen bids were received for the bonds on June 10. The low bid was $208,429.66 and the bonds were sold to the Guaranty Company of New York on the high bid of $210,717.45. Since the bonds were dated May 1, 1926 the purchase price included approximately $1025 for accrued interest and $4,692.45 premium.

The major conclusion to be drawn from this successful bond promotion campaign is that it pays to advertise. By means of advertising matter the voters were given the essential facts upon which they had to decide for themselves the merits of the proposition. If the proposition had provided for a concrete lining in the reservoir only it would have carried with practically no opposition, but the roof part of the proposition had to be sold to the voters. There are still intelligent men in Quincy who think that the water in the reservoir should be exposed to purifying rays of the sunlight.

After the proposition was sold to the voters of Quincy it was sold to sixteen contractors, who submitted bids on the construction work, by means of advertisements in the Engineering News Record,

in daily papers in Chicago, Galesburg, Davenport, St. Louis and Quincy. Nineteen dealers in bonds were also tempted to bid on the bond issue by advertising the sale in the Bond Buyer which is published in New York City. The keen competition brought about by advertising undoubtedly resulted in close figuring on the construction work and also in the bidding for the bonds.

Now that the job is done the people of Quincy are pleased with it and glad that it was put through.

THE DESIGN AND MAINTENANCE OF THE DISTRIBUTION SYSTEM[1]

By D. D. Gross[2]

The distribution system is probably the least interesting subject for discussion of any part of a water plant. Information compiled by Metcalf, Kuichling and Hawley, however, indicates that from 39 to 72 per cent of the money invested in a water-works is expended for its distribution system.

If, then, approximately half of the funds are invested on this one item, we should give the subject considerable thought.

DEFINITION AND FUNCTIONS

The distribution system consists of the net-work of distribution mains with fire-hydrants, valves and other accessories, which receives the water conveyed to it by the supply mains or conduits and delivers it over the area to be served in accordance with the needs of the community.

It must be capable of supplying water for ordinary consumption over the whole area served at a relatively uniform rate. But, it must also be able to supply the concentrated load at any point in the area necessary for the extinction of fires.

NECESSARY INFORMATION

Before any intelligent design for a new system or even an extension, addition or reinforcement to an old system can be made, certain information is necessary.

In addition to an inspection of the ground, this information is best given by a map, preferably a contour map, or in lieu of the contours, the relative elevations of important points should be known. The amount of water that will be required should also be known and may be determined from the number of consumers, the

[1] Presented before the Rocky Mountain Section meeting, February 23, 1926.

[2] Office Engineer, Denver Municipal Water Company, Denver, Colorado.

nature and amounts of their demands, and the nature of fire protection needed.

As most water mains are installed to serve for many years to come, all information that will assist the engineer in forming estimates as to the amount and nature of the future demands should be obtained.

In improving a system, and most of the engineer's work will consist in making improvements to systems already in use, tests of the present system should be made. As will be outlined later on, record of pressure conditions should be kept as part of the office records.

When an extension is being planned, these records should be consulted and supplemented by necessary additional field tests. These should include static and residual pressures and flow tests as described later on. They enable the engineer to determine the present condition of the system and are necessary in planning the improvement.

In cities having zoning laws, these should be of assistance to the water-works engineer in laying out or improving the distribution system. From the zoning map, he may learn the kind and the use of buildings that will be permitted in the future in any part of the city.

If the Fire Underwriters have made any recommendations affecting the work in hand, the engineer should familiarize himself with them. He should bear in mind that the total fire flow which should be available in an average city is best, but only approximately, computed by the National Board of Underwriters' formula:

$G = 1{,}020\sqrt{P}\,(1 - 0.01\sqrt{P})$, where G equals gallons per minute and P equals population in thousands.

From the above formula, we find that for the average city with a population of 1000 the required fire flow is 1000 gallons per minute; for 4000 population, 2000 gallons per minute; 10,000 population, 3000 gallons per minute, and so on until for a population of 200,000 the requirements are 12,000 gallons per minute; over 200,000 population, 12,000 gallons per minute with 2000 to 8000 gallons additional for a second fire.

In order to secure a high rating from the Fire Underwriters and a corresponding low rate of fire insurance, the "Standard Schedule for Grading Cities and Towns of the United States with Reference to Their Fire Defence and Physical Conditions," adopted by the National Board of Fire Underwriters, December 14, 1916, should be followed as closely as finances will permit.

PRESSURE

Perhaps the first point to decide upon in proceeding with the design is the pressure.

Perhaps this point is already decided and it is known that the supply will be received at a certain pressure. In that case, it is necessary to design the system to meet the conditions. The system should be designed not only to distribute the water, but to maintain an adequate service pressure, even when the draft becomes a maximum for which the system is designed.

Pressures may vary in different systems or at different points in the same system and still give satisfaction; but a wide variation at the same point, either at different hours of the day or at different seasons of the year, is sure to cause numerous complaints.

A repeated falling off in pressure is sure to displease the consumer and cause more complaints than a uniformly low pressure.

The actual pressures at the service connection or fire hydrant may vary from 20 to 130 pounds and give satisfactory service under certain conditions. If the pressure is only 20 pounds, the buildings served must be low and fire engines must be provided to give fire service, while 130 pounds pressure is probably more than most plumbing will stand unless it was installed for that high a pressure. The most desirable pressure for a residential district is from 40 to 75 pounds; but, if the district is large, the topography will probably make it out of the question to stay inside that limit and pressures will probably vary from 30 to 100 pounds. A desirable normal static pressure for a business district is 60 to 75 pounds, but it is better to exceed 75 than to fall under 60 pounds.

Topography frequently makes it impracticable to supply the entire city from one general system. It then becomes necessary to divide the city into zones according to the controlling elevations. In quite common cases, the lower zone includes the principal area of the city. Booster pumping stations, drawing from the distributing reservoirs raise the water to supply the higher outlying districts.

QUANTITY

The average daily consumption in cities varies from 40 to 250 gallons per capita. The quantity for the case in question should be estimated, taking into consideration the nature of the industrial and domestic needs, including lawn sprinkling or irrigation and add-

ing an allowance for leakage from city mains and service pipes. To this quantity should be added the amount required for fire protection.

MAINS

The Manual of Water Works Practice, published by The American Water Works Association, considers that, "Three classes of distribution mains appear in the make-up of a large system:

"1. Primary feeders, constituting the skeleton of large pipes with relatively wide spacing, convey large quantities of water to various points in the system for local distribution through the smaller mains.

"2. Secondary feeders, forming the net-work of pipes of intermediate size which reinforce the distributor grid within the various panels of the primary feeder system, and aid in the concentration of the required fire flow at any point.

"3. Distributors, consisting of the grid-iron arrangement of small mains serving the individual hydrants and blocks of consumers."

The writer has found it advisable, in laying out the first of the above classes, namely, the "Primary Feeders," to follow as closely as possible the high contour line of the district to be served. This plan makes for more uniform distribution as a general course of the flow through the smaller mains is down hill. But the greater pressure and shock otherwise obtained at the lower parts of the district, when a large quantity of water is being used, is to a considerable degree overcome by the friction in the pipes. In short, we have gravity and friction working in opposite directions and hence the pressure is more nearly uniform beween the high and low points of the district while the mains are performing their heaviest service.

The second class called the "Secondary Feeders" are best spaced at regular intervals in both directions. A plan found satisfactory in the residential districts is to use 12 inch mains and space them one-half mile apart in each direction.

The third class called "Distributors" should not be less than 6 inch mains. If laid in connection with the above mentioned 12 inch grid, they may be laid of 6 inch pipe on long side of the block and will give good service; but, in order not to be severely penalized by the Fire Underwriters when the district becomes closely built, it will be necessary to install 8 inch or larger cross connections.

In the business or high value districts, the minimum size main should be not less than 8 inch with frequent cross connections and 12 inch or larger mains on the principal streets.

HYDRAULIC COMPUTATIONS

The writer has found the "Hazen-Williams" formula satisfactory in computing the capacities of water mains and the "Williams and Hazen Hydraulic Tables" a means of obtaining results with much saving of time and labor.

CONSTRUCTION OF MAINS

Distribution mains may be installed of pipe manufactured from wood, steel or cast iron. Cast iron pipe manufactured in accordance with The American Water Works Association standard specifications is most generally used. It should be not lighter than what is known as Class B. While it is made in many sizes from 3 to 84 inches, the following are the most useful: 6, 8, 12, 16, 24, 30, 36, and 42 inches. It is not advisable to carry a large stock of pipe and specials on hand when nearly all the water works problems can be solved with the above limited number of sizes. Steel pipe may be obtained in any size desired, but here, as with the case iron pipe, it is well to adopt certain sizes as standard for the plant in question. Steel is a popular material for large mains, especially 48 inches and larger. It is becoming the practice to line both large cast iron and steel mains with cement. In making selection of pipe and other material an economic study should be made as to their adaptability for use under the existing conditions.

Water mains should be installed only by men familiar with the work. They should be laid in trenches of sufficient depth to insure their protection from frost and traffic. The pipe should be bedded on the virgin soil.

It is hardly within the scope of this paper to give specifications for the installation of the different kinds of water mains.

LEAKAGE

The leakage should not exceed 200 gallons per day per inch of diameter per mile of pipe.

GATES

Valves should be systematically placed with reference to street lines to facilitate their location. They should be installed on all branches from feeder mains. At street intersections where the grid iron mains are connected, it is good practice to have not less than three valves. If this rule is followed at each intersection, it is possible to shut out any block of pipe by the closing of not more than from two to four valves. If this rule cannot be followed, it is important at least to space valves so that it is not necessary to close more than five or six in order to gate off any given section of pipe. Valves of the double-disc type are in common use.

FIRE HYDRANTS

Fire hydrants should be set at each street intersection. If the blocks are long in the residential and in the business or high value district, they should be set at more frequent intervals in order to meet the Fire Underwriters' requirements. According to Fire Underwriter standards, "hydrants shall be able to deliver 600 gallons per minute, with a loss of not more than 2½ pounds in the hydrant and a total loss of not more than 5 pounds between the street main and outlet; they shall have not less than two 2½ inch outlets and also a large suction connection where engine service is necessary." "They shall be of such a design that when the hydrant barrel is broken off the hydrant will remain closed." "Street connections shall not be less than 6 inches in diameter and shall be gated."

DISTRIBUTION STORAGE

Storage reservoirs or tanks connected to the distributing system are a great advantage. They not only make for economic construction, making it possible in some cases to reduce size of mains or operate the plant at less cost, but, in case of accident, provide a supply for emergency use. If the water supply is filtered or obtained from ground-water, the reservoir or tank should be covered to shut out the sunlight and thus prevent vegetable growth in the water.

DEAD ENDS

Dead ends are the bane of a water-works man's life. They should be avoided wherever possible and eliminated at the first oppor-

tunity. Where they cannot be avoided, which is often the case in outlying districts, means should be provided for flushing them. It is a good plan to set a fire hydrant at the end of the main even though the supply of water may be small for fire protection.

RECORDS AND TESTS

Records in the form of maps should be kept to show the location of each main together with the location of all specials, valves and hydrants. It is preferable that mains should always be laid a certain distance from the property line and on a given side of the street, and that the lines should be actually laid out by a surveying party. It is also good practice for the engineering party to set grades for all the larger mains. Mains that wander about from side to side of the street are the cause of a great deal of distress when it becomes necessary to lay additional mains or other underground structures in the street.

At prominent points in the system, continuous records of pressure should be kept by recording gauges. At frequent intervals, if the city is growing rapidly, tests should be made at the fire hydrants in all parts of the system.

These should consist of taking the static pressure at the fire hydrant; the residual pressure on the hydrant with one or more neighboring hydrants open; the discharge from the open hydrant nipple measured with a Pitot tube or flow gauge. The results of these tests together with the date and time of day they were made should be kept as a matter of record. For this purpose, a card system is best.

When installing primary feeders it is a good plan to make connections and construct vaults to facilitate pitometer measurements. By this means, the use of water among the several principal districts of the city may be learned.

ELECTROLYSIS

In case the mains are subject to electrolytic corrosion due to stray electric currents, an electrolysis survey should be made to determine the nature of damage already done and the measures that may best be employed for reducing the damage in the future.

REPORT UPON THE PRACTICABILITY OF STANDARDIZING METER DIALS[1]

By The Joint Committee upon Standard Specifications for Water Meters

Your Joint Committee upon Standard Specifications for Water Meters was instructed to investigate the practicability of a standard meter dial.

As it would obviously be useless to devise such a standard unless there were a real demand for it, and unless it would be generally used if adopted by the Association, the Committee prepared a questionnaire which was sent to 34 of the largest water works in the country, including both municipal and company owned plants. Replies were received from 23 works in which there are now in use approximately 1,150,000 meters of which about 900,000 have round reading and about 250,000 have straight reading registers.

Seventeen of the plants use meters reading in cubic feet and six meters reading in gallons, including in the latter category one large holding company which controls several water plants, some of which use meters reading in gallons and others in cubic feet, but the majority of which are in gallons.

The most significant question was whether in case a standard meter dial for round reading meters were adopted by the associations, the water departments would be inclined to adopt the standard, even though it might involve a slightly increased cost of meters? To this inquiry eight affirmative answers were received; three plants use no round reading meters, and four replied unequivocally that they would not adopt a standard different from their present practice, among these being some of the very large water works.

Eight of the replies did not contain answers to this question.

With regard to a standard unit of measurement, whether gallons or cubic feet, nearly everyone agreed that it was desirable to have a standard, but wished that standard to be the unit which is now in use. Only one would be willing to adopt a standard differing from

[1] Presented before the Buffalo Convention, June 8, 1926.

the present practice, leaving 22 who stated unequivocally that they would not change to a different standard.

The results of this questionnaire indicate that, in spite of the unfortunate differences in arrangement of meter dials, less than half of the large water works would be willing to adopt a new standard if it differed from their present practice, especially if any increase in cost were involved, and practically none if it made a change from gallons to cubic feet or vice versa.

Some of the replies received indicated that it may prove advantageous to adopt the straight reading register to a much greater extent than is now common, in place of the round reading register. The disadvantage of the various types of round reading register and the advantages of the straight reading register are well shown in the following quotation from a letter accompanying the questionnaire, submitted by H. P. Bohmann, Superintendent of Water Works at Milwaukee:

> If a standard round dial were adopted, I would like to make a few suggestions in regard to construction. Such dials regardless of size or capacity should all be constructed with the one foot or test circle at the bottom of dial with other circles grouped around it in such a way from small to large so that largest circle would be to the left of the one foot or test circle.
>
> A great majority of meter dials in service in this city are arranged as above recommended, but we have quite a few very much at variance with that arrangement. Some have the one foot or test circle at the top of the dial with the other circles grouped aroung from small to large to the right; others to the left; and some with the largest circle at the middle of dial.
>
> Others, where the one foot or test circle is at bottom as recommended, have the circles grouped around it in such a way as to bring the largest circle to the right of the test circle.
>
> You can readily understand that considerable confusion exists with so many different arrangements of circles on dials, and errors in readings are bound to occur.
>
> Compound meters are equipped with two dials, one recording the consumption for the small end of meter and the other the consumption of large end.
>
> Some types of compound meters have both dials of the same size and capacity.
>
> On account of the great difference in the construction of compound meters, some having the large end on the inlet side while others have the large end on outlet side, if both dials are of same size and capacity, considerable confusion exists at all times when taking readings, and where one or the other dial stops registering difficulty is encountered in properly averaging the consumption and an incorrect average may result.

Dial controlling the small end of a compound meter should have at least one circle less than the dial controlling the large end.

If the American and the New England Water Works Associations expect to adopt a standard dial for water meters, I would suggest that the matter of a straight reading dial be given consideration. The advantages of a straight reading dial are very apparent on account of its simplicity for taking readings, it being only necessary for reader to copy numerals from left to right as shown, with danger of error reduced to a minimum.

With round dials more or less difficulty exists at all times in obtaining correct readings. If, as is frequently the case, one or more hands are slightly out of alignment, it requires study to determine the correct reading. It also requires visualizing all the circles, especially where the hands are in such a position that it becomes necessary to consult a next lower circle or circles before correct reading can be obtained. Over and under readings, I believe, would be practically eliminated by the use of the straight reading dial. Further, much greater speed could be obtained in taking readings.

I believe that formerly the chief objection to the straight reading dial was the difficulty in getting it to operate properly. The mechanical improvements made in late years, I am satisfied, have completely removed that objection.

Recommendation. In view of the replies received, your committee recommends that no further attempt be made to standardize dials of round reading meter registers.

Respectfully submitted for the Joint Committee,

CHARLES W. SHERMAN,
Chairman.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Fifth Annual Report of Ohio Conference on Water Purification Held at Akron, Ohio, October 15–16, 1925. 85 pp. The following points of interest were reported in general discussion. Addition of lime to the raw water at Akron to correct corrosiveness was found to interfere with coagulation and the chemical is now applied to the filtered water, a convenient place having been found in clear well under filters which can be gated off to remove sludge. It is pointed out that basins should be provided in new plants for such secondary treatment prior to filtration. Clogging of feed lines has been eliminated by substitution of rubber hose for metal pipe. Experience with ultra violet ray sterilization at Berea has shown that while this method is satisfactory when water is clear and reasonably free of color, it is not effective with slightly turbid waters. Another difficulty encountered has been the burning out of lamps without warning. The apparatus costs about 10 times as much as liquid chlorine equipment. Breakage, during cold weather, of valves and pipe which were free of water was reported at Camp Perry, Cedar Point, and Cincinnati. Permanent equipment, consisting of sand bin, piping and ejector for moving and scrubbing filter sand, has been installed at East Liverpool. Sweating of pipes in pipe gallery at Glendale has been eliminated by covering with combination of layers of felt and asbestos, with final covering of asbestos. At Medina a covering of medium grade asbestos paper, over which was applied one or two layers of paste made from caustic soda and starch, is used for this purpose. Serious incrustation of mains and services has occurred at Oberlin, where the oldest municipal softening plant in the United States (installed in 1903) is situated, and one of the large raw water storage reservoirs has been converted into softened water reservoir in hope that natural recarbonation by absorption of carbon dioxide from atmosphere will occur during 30–40 days' storage thus provided. The design of the coagulation basins at Norwalk, which can be used either in parallel or series, is described. A new type of Gauntt dry feed machine is being employed at Westerville which eliminates difficulties due to arching and packing of chemicals. In discussion regarding the amount of sodium sulphate required to render water laxative, it was stated that at Oberlin and Columbus, with contents, respectively, of 200 and 300 p.p.m., some complaints are received, but only from visitors or those who have been away for some time. One community in Montana was reported to be employing water containing 1700 p.p.m. of sodium sul-

phate. Foaming in boilers occurs to marked extent when this salt is present in concentration of 3000 p.p.m. LEON G. HALL is quoted as having reported (Chem. and Met. Eng. 32: 12, 582) that persistent soreness and congestion of throat and lungs following exposure to chlorine may be prevented if steam containing vapor of benzoin is inhaled as soon as possible after exposure. Water is heated to boiling in open pan, 6 to 10 drops of tincture of benzoin are added, and the steam is inhaled for 5–10 minutes while liquid is kept boiling. **Activities of the State Department of Health with Reference to Stream Pollution.** C. C. HOMMON. Pp. 8–13. Activities in regard to stream pollution in Ohio are reviewed. Legislation enacted in 1925 provides for approval of State Department of Health of plans for proposed treatment of municipal sewage and industrial wastes, and authorizes that body to adopt regulations necessary for preventing undue pollution. A survey of streams of state for purpose of determining major sources of pollution has been almost (90 per cent) completed. **Progress on Seal of Safety Campaign.** C. S. SLADE. Pp. 13–18. Progress in work of locating and marking safe public and semi-public water supplies in rural districts in Ohio is reviewed. Supplies are judged by (1) quality of water, (2) development of supply, and (3) sanitary conditions of vicinity. Of 1443 supplies examined, 105 or 7.28 per cent were found satisfactory, as follows: drilled wells 102, dug well 1, springs 2. **Akron Water Works System.** J. S. GETTRUST. Pp. 46–50. Akron water supply system is described and illustrated in 3 figures. Supply is drawn from the Cuyahoga River above impounding dam 12 miles upstream which creates reservoir of 2.39 billion gallons known as Lake Rockwell. Dam is of hollow concrete type. Plant consists of hydroelectric station, nozzle aërator, mixing chambers, 2 coagulation basins each of 2 m.g. capacity providing retention period of 2 hours and velocity of 2 feet per minute when operated in parallel at maximum plant capacity of 50 m.g.d., and 25 2-m.g. concrete gravity filters equipped with Wheeler bottoms, the sand used having an effective size of 0.40 mm., and uniformity coefficient of 1.29. Rate of wash employed is 18 to 21 inches vertical rise per minute. Lime is applied to filtered water to correct corrosiveness. Typhoid death rate in 1925 was 1.0. Total investment is nearly $11,000,000. **Prechlorination of Ohio River Water at Ironton Water Purification Plant.** E. T. EDWARDS. Pp. 51–3. Prechlorination was experimented with at Ironton during past year in effort to reduce the heavy bacterial load on coagulation and filtration processes. Plant consists of primary and secondary coagulation basins, four 1-m.g.d. filters and 4-m.g. clear water reservoir from which water is distributed by gravity. Double coagulation is regularly employed. Average bacterial content of raw water during 1924 was: agar count, 20°, 28,800; agar count, 37°, 12,800; B. coli index per 100 cc., 16,690. Two experiments were carried out; (1) 0.2 to 0.8 p.p.m. of chlorine was applied to raw water, no residual chlorine being present in filter influent; and (2) 2 p.p.m. of chlorine was applied to raw water, the excess chlorine being removed by addition of sulphur dioxide after 12 to 24 hours contact. Complete removal of chlorine was effected by application of sulphur dioxide at rate of 90 per cent of residual chlorine content of water. Excellent bacterial results were obtained but both treatments had to be discontinued owing to production of tastes due to presence of algae and phenols.

The chlorophenol taste was not destroyed by the latter treatment. **Research on Gas-Former Resisting Chlorination in Filtered Water at Akron.** C. O. HOSTETTLER and J. S. GETTRUST. Pp. 54–5. An organism is described which gives rise to a large number of presumptive B. coli tests at Akron which do not confirm. Of 3195 positives during 1924–1925 only 15 confirmed on Endo medium. Organisms ferment lactose broth only after 24 hours incubation and as little as 0.025 per cent of dried bile will inhibit its growth. Lactose-fermenting power is lost in pure culture. The organism withstands chlorine concentrations up to 0.5 p.p.m., but higher concentrations are lethal. Latter treatment cannot be employed owing to taste imparted to Akron water by high doses of chlorine. In discussion it was stated that split chlorine treatment was successful in eliminating similar trouble at Toledo. **Correction of Raw Water pH Value by Means of Carbon Dioxide.** E. E. SMITH. Pp. 57-9. Although the raw water at Lima is of good physical and bacterial quality, it has been found necessary to apply 3 or more grains of alum per gallon to effect adequate coagulation. The pH value of the raw water is 8.0 to 8.3 and that of the treated water is almost invariably in region of 7.0, irrespective of raw water conditions. Adjustments of pH with sulphuric acid were found to be economically ineffective, and as it had been observed that application of carbon dioxide to the water in the laboratory aided floc formation, this treatment has been experimented with on a practical scale. Application of approximately 10 p.p.m. of carbon dioxide generated from coke to raw water just prior to addition of coagulant reduced the cost of chemicals from $5.80 to $4.80 per m.g., and the improved flocculation obtained increased the length of filters runs and reduced the waste water from 6 to 4 per cent. No tastes or odors have been experienced as consequence of treatment. The results obtained seem to warrant a permanent installation of greater efficiency. In discussion it was stated that two optimum points for coagulation had been noted at Columbus, one at pH 5.5 and other at pH 9.0 to 9.5. Between pH 5.5 and 8.0 poor flocculation occurs. **Methods of Recarbonation of Lime-Soda Softened Water.** CHAS. P. HOOVER. Pp. 60–63. History of recarbonation of softened water is reviewed briefly and methods used at different plants are described. Of various reagents experimented with, carbon dioxide has been found most suitable. Available fuels from which carbon dioxide can be generated and their respective yields are: coke, 3 pounds per pound of fuel; natural gas, 115 pounds per 1000 cubic feet; artificial gas, 82 pounds per 1000 cubic feet; and kerosene, or similar oil, 20 pounds per gallon. Use of soft coal has given rise to tastes and other troubles. For large installations, producer gas prepared from coke and then burned to complete combustion is most economical method of generating carbon dioxide. In this way a content of 17 per cent carbon dioxide can be attained as compared with 12 per cent from gas and oil and 4 to 6 per cent from coke burned in open furnace or retort, and the compressor capacity required correspondingly reduced. In discussion it was stated that some trouble had been experienced with phenol tastes at plants using 8-hour coke, but that this was eliminated by employment of 72-hour coke. The feasibility of generating carbon dioxide by burning limestone in a small electric furnace was also discussed. Not only would this method give a higher percentage of carbon dioxide, but the quicklime pro-

duced would be available for use in the softening process. Limestone costs $4 to $5 per ton while lime is worth $10 to $12 per ton. **Boiler Feed Water Treatment by the Permutite System.** CLARENCE BAHLMAN. Pp. 64–67. The boiler feed water employed at Cincinnati consists of oil-freed condensate and 16 to 20 per cent permutite-softened make-up. This system has been in use 3 years, during which time no trouble has been experienced from foaming. The average total hardness of Cincinnati filtered water is about 105 p.p.m., of which 60 p.p.m. is permanent and 45 p.p.m. temporary. The condensate is treated with ammonium alum and caustic soda (7.5 and 3.75 g.p.g. respectively) to coagulate the oil and passed through a filter of the pressure type. The filter is back-washed daily and the sand thoroughly cleaned with steam and caustic soda every 6 weeks. The softening process is controlled by the soap test. A recent examination of the effluent when the water being treated had hardness of 144 p.p.m., gave the following results: soap method 0; soda-reagent method 14 to 20 p.p.m. Titration of calcium oxalate precipitate gave results slightly higher than latter. Amount of salt used for regeneration is 10.3 to 12.8 pounds per 1000 gallons of water softened or 1.7 to 2.0 pounds per 1000 grains of hardness removed, equivalent to cost of $.0623 to $.0772 per 1000 gallons. Total cost of chemicals is approximately $.065 per 1000 gallons of boiler feed water. In discussion it was stated that salt requirement of the newer zeolites is only 0.5 pound per 1000 grains of hardness removed. **Comparison of B. coli Content in Raw and Filtered Waters in Ohio.** F. H. WARING. Pp. 76–80. Tabulated data given showing the B. coli content of raw and filtered water of 31 plants in Ohio. In 17 of plants considered, B. coli content of raw water exceeded tentative limit of 500 per 100 cc. fixed by International Boundary Commission, but without exception all the plants produced water with B. coli content of less than 1 per 100 cc. after chlorination. **Conservation and Utilization of Water Resources in Pennsylvania.** H. E. MOSES. Pp. 81–2. Activities of the Sanitary Water Board of Pennsylvania in combating stream pollution is reviewed briefly and system adopted of classifying streams according to water quality is described. **Progress of Seal of Safety Campaign in Pennsylvania.** H. E. MOSES. P. 83. Progress in examination of water supplies on state highways in Pennsylvania is reviewed briefly. Sanitary surveys of the supplies were carried out and samples from those approved were examined in traveling laboratory. Approximately 50 per cent of supplies approved by sanitary engineer were found to be of satisfactory bacterial quality. **Preliminary Report on an Investigation of Chlorine-Resistant Lactose-Fermenting Bacteria in the Public Water Supply of Akron.** FRED BERRY. Pp. 84–5. Numerous attempts to isolate an organisms which would ferment lactose in pure culture from presumptive tubes inoculated with Akron water which had fermented after 24 hours incubation were unsuccessful. On most of the eosine methylene blue plates made there were two types of colonies which when introduced together into lactose broth, either direct from plate or from pure culture, formed gas rather promptly. Results obtained would indicate that gas production in the presumptive tubes was due to symbiotic growth of the two bacilli mentioned, neither of which seem to correspond to the spore-forming types reported by other workers.—*R. E. Thompson.*

Report of Bureau of Sanitary Engineering, Maryland State Dept. of Health, 1925. ABEL WOLMAN. 23 pp. Activities of Bureau during 1925 are reviewed and discussed. Total value of work in passage through Bureau, in form of plans submitted for review, aggregated approximately $3,500,000, compared with $2,012,300 during 1924. New works for treatment of water and sewage, and additions to existing plants carried out during the year are described briefly. Special studies conducted included investigations of sanitation of oyster industry in state, and of stream pollution by wastes from congoleum factory, garbage reduction plant, lithopone works, creameries, and tanneries. Tables are given showing typhoid death rate, inclusive and exclusive of Baltimore, for years 1910-1925, and distribution of deaths from typhoid fever in relation to population groups for years 1920-1925. Rate during 1925 was 7.6 and 11.7 inclusive and exclusive of Baltimore respectively, compared with 6.4 and 10.3 in 1924. Similar increase in typhoid mortality has occurred throughout the entire United States. Study of typhoid data indicates that 60 to 75 per cent of total deaths occur in populations under 500 and in Baltimore City, where deaths have been so scattered as to have no relation, probably, to water supply quality, and that efforts towards further reduction of typhoid death rate must involve discovery of causes of widely distributed and isolated groups of typhoid fever which are independent of large aggregates of population. Improvement in efficiency of water supply control in populations in excess of 500 cannot decrease typhoid mortality by much more than maximum of 25 per cent.—*R. E. Thompson.*

The Swimming Pool and Its Sanitation. JACK J. HINMAN, JR. Iowa Health Bull., 1: 4, 2-30, October-December, 1925. Lengthy treatise on sanitation of swimming pools, including discussion of design and construction of pool and of water purification by filtration and by treatment with ultra violet light, ozone, hypochlorite, and chlorine.—*R. E. Thompson.*

Phenol Waste Pollution. D. M. WATT. Penna. W. W. Assn., 1925 Report. Page 24. Reciting experience of the American Water Works and Electric Company with phenol waste pollution.—*E. E. Bankson.*

Softening Plant of the Ohio Valley Water Company. By H. C. KNEELAND. Penna. W. W. Assn., 1925 Report. Page 40. The Ohio Valley Water Company has just put into operation the largest zeolite water softening plant in the world and the first to supply an entire community with softened water. The objectionable elements of this water supply are its hardness, manganese, and crenothrix, all of which are successfully treated by this process. Any desired degree of softness is obtainable. Zeolite system is practically foolproof, eliminates all danger of over or under-dosing, and can be built in very little space.—*E. E. Bankson.*

Studies upon Effect of Water Rates and Growth of Population upon per Capita Consumption. LEONARD METCALF. Penna. W. W. Assn. 1925 Report. 1. Annual or periodical data assembled at 5 year intervals are badly needed. 2. Average increase in per capita daily water consumption with

increase in population, appears to be about 10 per cent of increase in population. 3. Average decrease in per capita consumption with increase in rates is indicated by figures and diagrams. 4. Figures show that relative per capita consumption increases with decrease in water rate and vice versa, as indicated. 5. The figures indicate an average annual rate of increase in per cent in per capita water consumption of $\frac{1}{4}$ of 1 per cent per decade. The foregoing analysis is supported by tabulations and diagrams.—*E. E. Bankson.*

Extensions of Water Mains. W. C. Hawley. Penna. W. W. Assn., 1925 Report. Page 70. Many decisions are quoted regarding extensions of water mains and a method is formulated to determine the justifiable investment by the utility, in relation to prospective consumers.—*E. E. Bankson.*

Wild Life and Water Supplies. Seth E. Gordon. Penna. W. W. Assn., 1925 Report. Page 111. After describing activities of Game Commissioners in establishing refuges for protection of desirable wild life, author states that: "In a number of instances water companies have gladly leased to the of Game Commissioners the hunting rights on their holdings with the understanding that an auxiliary game refuge will be established on that portion covering the reservoirs or dams and the principal feeder streams. If the various water companies of Pennsylvania will turn over the hunting rights on their lands to the State Game Commission, I am confident many of their present difficulties will be overcome."—*E. E. Bankson.*

Suggested Rules for the Care of Power Boilers. Power, **61**: 24, 964, June 16, 1925. Presented at public hearing at A. S. M. E. Spring Meeting in Milwaukee; proposed as an addition to A. S. M. E. Boiler Construction Code. They relate to operating and maintaining boiler appliances such as pressure gages, water glasses, feed-water regulators, fusible plugs, safety valves, blow-off equipment, dampers, and to banking fires. Power, **61**: 25, 1007, June 23, 1925. Rules for inspection include preliminary inspection, external inspection, furnace and parts exposed to fire, appurtenances, and care and management. Power, **62**: 1, 33, July 7, 1925. Rules for prevention of direct causes of boiler failures. Equipment included are steam pressure gages, water glasses, fusible plugs, and safety valves. Rules for fuel supply and damper regulation are included; also rules for manipulation of valves. Power, **62**: 2, 72, July 14, 1925. Further rules deal with excessive combustion, secondary combustion and flaming through, localized and uneven heating, damper regulation, control of water supply, control of water level, blow-off equipment, and blowdown regulation. Power, **62**: 4, 150, July 28, 1925. Further rules deal with feed-water treatment and corrosion: general, boiler compounds, heater equipment, treatment regulation, care of heating surfaces, gases in feed water, boiler out of service, and leaks. Also erosion, stresses other than internal pressures, failure of supports, mechanical injuries, tube cleaning or scaling, and loose connections. Power, **62**: 5, 187, August 4, 1925. Deals with partial rules for installation: boilers, steam pressure gages, water glasses, safety valves, intercommunicating valves between systems of different pressures, feed-water supply, blow-off line and valves,

support for structures, pipe line supports, stack supports, and belting and shafting supports.—*Aug. G. Nolte.*

Submerged Storage and Coal Handling Equipment at Philo. Power, 61: 25, 976, June 23, 1925. Storage facilities provided for two general grades of fuel. Submerged-storage basin is mainly for cheaper grades, as screenings, etc., which easily may catch fire due to spontaneous combustion. The dry-storage area is for better grade and larger sized coal, which can be stored safely on the ground in thicker layers without heating; this area also serves for drainage of fuel reclaimed from submerged storage. The handling equipment has been designed to function with great flexibility. Outstanding features are the systematically arranged facilities for unloading and distributing the different grades of coal into storage; the reclaiming from storage and mixing of grades so as to maintain uniform quality in the bunkers.—*Aug. G. Nolte.*

Putting Alternating-Current Generators Into Service. N. L. Rea. Power, 61: 25, 980, June 23, 1925. Suggestions and instructions given are especially valuable to a new man. Thorough inspection before starting is advocated. A method of determining the condition of the windings with respect to moisture is illustrated and described. Other items discussed are; drying out the generator, measuring the temperature, starting up the machine, checking phase rotation, and phasing out with transformer and lamps.—*Aug. G. Nolte.*

Operation of Diesel Engines. R. Hildebrand. Power, 61: 25, 989, June 23, 1925. Proper adjustment of fuel spray valve is essential to good combustion conditions.—*Aug. G. Nolte.*

How to Lay Out Power-Plant Piping. S. Crocker. Power, 64: 1, 16, July 6, 1926. Drips and drip systems, by-pass valves, and guard valves are discussed.—*Aug. G. Nolte.*

Commutator Maintenance. N. L. Rea. Power, 61: 26, 1020, June 30, 1925. Methods and tools for undercutting commutator mica are discussed. —*Aug. G. Nolte.*

Remodeled Powdered Coal Furnace Doubles Boiler Capacity at Fordson Plant. Power, 64: 2, 40, July 13, 1926.—*Aug. G. Nolte.*

Maintaining Surface Condensers. H. Wottrich. Power, 64: 3, 82, July 20, 1926. To test for leakage in condensers, salinity determinations on condensate are made each half hour by operator. Each condenser is cleaned at least once a week by means of rubber plugs and air and once every three months with steel brush. Tubes difficult to reach with ordinary steel brush are cleaned with special tool consisting of an expansible rubber plug attached to brush. Sand-blast method of cleaning tubes has been tried, but, although producing good results, is hard on the men. Old stationary wooden platform

from which men cleaned tubes was replaced by movable one, with steel frame work.—*Aug. G. Nolte.*

Control Operates Three Pumps in Six Combinations. A. F. BOWERS. Power, **64:** 3, 92, July 20, 1926. System of pump-motor control devised for controlling installation of three squirrel-cage pump motors used to maintain water level in a reservoir is described.—*Aug. G. Nolte.*

Venturi Meters Used in Hydro-Electric Plant Operation. J. M. GAYLORD. Power, **62:** 4, 137, July 28, 1925. Meters indicate, record, and integrate flow of water to wheels. Head on meters ranges from 800 to 2130 feet.—*Aug. G. Nolte.*

Questions and Answers. FRANKLIN VAN WINKLE. Subjects as follow: Power, **61:** 24, 960, June 16, 1925, Greater Chimney Capacity from Increase of Height; Warping of Fire Tubes of Boiler; Length of Open Belt; Noisy Admission Valves of Low-Pressure Cylinder; Vacuum Line on Indicator Diagram; Location of Air Intake for Forced Draft; Removing Oil from Exhaust-Steam Heating System; Transformer Connections on a Four-Wire Three-Phase Circuit; Multiplying Sheaves on Hydraulic Elevators; Steam Consumption of Unaflow Engines. **61:** 25, 1003, June 23, 1925. Poorer Economy with Shorter Cutoff; Piston Clearance with Given Length of Connecting Rod; Overheated Grate Bars of Dutch Oven Furnaces; Drumming Sound in Water-Tube Boiler; Cause of Lights Flickering; Cushion of Duplex Pump; Inspection of Transformers. **61:** 26, 1042, June 30, 1925. Angle of Advance of Eccentric; Increase of Feed-Water Temperature at Expense of Back Pressure; Valves on Hydraulic Elevators; Finding Range of Cutoff; Use of Ammonia Condensers Without Cooling Water; Principal Scale Forming Impurities in Feed Waters; Theoretical Intake of Air Compressor; Slotted Eccentric on Shaft Governor. **62:** 1, 27, July 7, 1925. Advantage of Outside Packed Piston Pump; Single-Strap Butt Joints; Bent Rocker on Single-Valve Engine; Connections for Drinking Water System; Larger Safety Valve for Lower Pressure; Single-Riveted Girth Joints; Thermal Efficiency of Turbo-Generator Set; Inclined Grate for Hand Firing; Detecting Ammonia in Brine; Operation of Steam Loop; Provision for Drainage of Superheated Steam Lines. **62:** 2, 67, July 14, 1925. Star-Delta Connected Transformers; Importance of Boiler Circulation; Vacuum Chamber; Turbine Efficiency Reduced at Light Load; Measuring Angle of Advance of Eccentric; Degree of Vacuum Not Shown by Temperature; Safe Working Pressure for Boiler Shell. **62:** 3, 108, July 21, 1925. Arrangement of Manhole; Adjustment of Lead of Corliss Engine; Ratio of Expansion; Advance of Eccentric of Single-Eccentric Corliss Engine; Placing Anchor Bolts in Old Foundation; Packing for Gage Glass of Gasoline Tank; Flow of Steam Into Lower Pressure, Advantages of Poppet Valves; Air in Suction Water. **62:** 4, 148, July 28, 1925. Knocking of Duplex Pump; Causes of Excessive Flue-Gas Temperature; Air Required for Burning Coal; Submerged Piston vs. Straightway Pumps; Cause of Flat Spots on Collector Rings; Locating High Side of Eccentric; Standard of Evaporation. **62:** 5, 184, August 4, 1925. Governor with Single

Reach Rod; Reversing Engine with Shaft Governor; Determining Alignment of Engine Guides; Capacity of Wooden Tank; Pitch of Steam Main; Rusting of Steel Stack; Brake for Testing Waterwheel.—*Aug. G. Nolte.*

Water Softener Lowers Boiler Maintenance. Power Plant Engineering, 30: 8, 472, April 15, 1926. Installation of hot-process softener in Mich. Cent. R. R. power plant at Jackson, Mich., reduced time required for cleaning boilers from 21 to 4 days and cost by over $3500 per year.—*W. U. Gallaher.*

Air-Lift Pumping Pays Dividends for Oil Plant. D. W. Moore. Power Plant Engineering, 30: 8, 488, April 15, 1926. Air-lift pump made from scraps welded together is used for circulating cooling water.—*W. U. Gallaher.*

Mechanical Pressure Filter Has No Strainer Heads. Anon. Power Plant Engineering, 30: 8, 502, April 15, 1926. Filter designed by Cochrane Company of Philadelphia has conical shaped bottom for reception of gravel. An inverted cone at bottom of gravel is used for withdrawal of filtered water and introduction of wash water.—*W. U. Gallaher.*

Proper Filters Aid Ice Plant Operation. C. H. Herter. Power Plant Engineering, 30: 8, 493, April 15, 1926. Abstract of paper by M. P. Robinson given before New York Chapter No. 2, N. A. P. R. E. A short review of theories and practices in sand filtration.—*W. U. Gallaher.*

Pumping Plant Utilizes Automatic Control. Anon. Power Plant Engineering, 30: 10, 586, May 15, 1926. Three pumps controlled by automatic switches keep reservoir full. During a prescribed shut-down period control is automatically removed and only one pump operates.—*W. U. Gallaher.*

Application of Centrifugal Pump Chart Limited. B. Marker. Power Plant Engineering 30: 11, 663, June 1, 1926. Criticism of article by Charles Fromm, same Journal, 30: 438. Best way to determine changes to be made on pump is to run characteristic curves and compute from them.—*W. U. Gallaher.*

Pipe Welding Proves Economical. H. A. Woodworth. Power Plant Engineering, 30: 12, 706, June 15, 1926. Steel and wrought iron pipe from 1-inch to 30-inch can be easily welded with oxy-acetylene. Nickel steel rod most resistant to corrosion. Precautions and directions for welding are given.—*W. U. Gallaher.*

Water Treatment for Raw Water Ice Plants. W. N. Waterman. Power Plant Engineering, 30: 13, 758, July 1, 1926. First question to consider in installing ice manufacturing plant is quality of raw water. Chemical impurities are sure to cause an inferior product. Use of sodium carbonate to remove permanent hardness unnecessary. Core removal should be effected when concentration of calcium carbonate reaches 60 grains per gallon. Treatment of a 20 grain per gallon water means a saving of 8 per cent in refrigera-

tion costs. Zeolites do not produce good water for ice manufacture because the total concentration of dissolved salts is not lowered.—*W. U. Gallaher.*

Boiler Feed-Water Purification—4. Softening Water by Chemicals. SHEPPARD T. POWELL. Power, 64: 4, 129, July 27, 1926. Chemical precipitation water softeners depend for their operation upon the addition of certain chemicals which convert the soluble scale-forming solids into insoluble forms which are removed by settling or filtration. They may be either of intermittent or of continuous type. Many different designs of softeners now on the market differ principally in construction details and in respect to the temperature at which treatment takes place. Intermittent softeners are operated on fill-and-draw plan, the system consisting usually of two or more tanks, one supplying soft water that has been previously treated, while the others are being filled and treated with softening reagents. The most frequent form consists of two circular tanks equipped with inlet and outlet pipes, sewer connection for removal of sludge, chemical dosing apparatus, etc. Filters may or may not be employed to clarify effluent. Efficiency of softeners is influenced by temperature of water, time of reaction and settling, accurate proportioning of chemical, etc. Continuous softeners are favored for stationary plants. They soften the water while it flows through the apparatus, which usually consists of tank with baffling arrangement, apparatus for feeding chemicals, means for agitation, and compartments for chemical reaction and settling of precipitate. Water is treated with the chemicals at entry and dose is proportioned to its volume and hardness. Filters of sand, non-siliceous material, or excelsior, generally employed to remove the finely divided precipitate that has not settled in softener. Other things being equal, efficiency of softening apparatus will be proportional to uniformity of chemical dosage. Mixing must be thorough and efficient. Use of filters in connection with continuous softeners, whether hot or cold, is now generally considered essential. Pressure filters are mostly employed. Principal difficulty encountered in operation of sand filters in connection with cold softeners is incrustation of sand grains causing them to increase in size and at times to cement together into patches. As a rule intermittent softeners permit of more accurate dosing of chemicals. Continuous softeners are preferred as being much smaller, one tank only being required. Cost of operation of cold softeners fluctuates greatly. Including capital and operation costs, it will fluctuate from about two cents to ten cents per thousand gallons of water treated. The saving resulting will warrant any form of treatment when appreciable amounts of scale-forming solids are present. Several continuous cold softeners are illustrated. **5. Hot-Process Continuous Softeners.** Power 64: 5, 165, August 3, 1926. The hot-process chemical softener is a combination of open feed-water heater and softener in which scale-forming solids are removed in part by effect of heat and in part as result of chemical reaction. Velocities of reactions are increased tremendously as temperature increases. Rate of precipitation is also increased. Essential features of hot softener are: (a) heater for raising temperature of raw water to 200°F., or higher; (b) chemical dosing apparatus; (c) subsidence and reaction tank; (d) filter. Various designs of softeners differ primarily in construction details

and in method of heating water for which exhaust or live steam may be used. In one design heating is accomplished by spraying water over trays, which releases majority of carbonic acid, thereby causing precipitation of calcium and magnesium carbonates. Dissolved oxygen and other gases also released. Chemical reagents are added as water flows into subsidence chamber. High temperature causes rapid precipitation of solids into conical bottom hopper. Softened water, partially clarified, passes upward in a funnel and through a pressure filter, where remaining suspended solids are removed. Clarified soft water is discharged directly to feed-water pumps or to storage tank. It is essential that sludge compartment of softener be of sufficient size to hold all solids precipitated between blowdowns. Removal of sludge from softeners is important. Frequency of blowdown periods should be governed by volume of water softened and amount of sludge produced. For a number of years sand and other siliceous materials were used as filter media for clarifying treated water from hot-process softeners. Recent studies have demonstrated that hard dense calcium silicate scale may form in boilers as result of passage of hot alkaline solution through siliceous filter. To overcome this difficulty, magnetite, calcite, and other substances are now being employed in place of sand. Hardness of water may be reduced by hot softeners to from 2 to 3 grains per gallon and even lower by careful control. Various hot-process softeners are illustrated. **6. Zeolites Explained.** Power, 64: 6, 208, August 10, 1926. Water may also be softened by passing it through a bed of base-exchange silicates, termed zeolites, which possess the property of removing calcium and magnesium from water, replacing them with sodium (or potassium). Softening continues until practically all replaceable sodium has been exhausted. At this point the zeolite may be regenerated by treatment with solution of sodium chloride (common salt). The calcium and magnesium extracted from the water by the zeolite now pass into solution in the brine and their equivalent of sodium is again taken up by the mineral. There are a fairly large number of natural base-exchange minerals, and several products are manufactured that possess base-exchange properties. Chemical formulas of different materials vary, but most of them are hydrous silicates of sodium and aluminum. A number of qualifying terms have been used to describe the various zeolites used in water softeners, such as natural, artificial, synthetic, slow regeneration, rapid regeneration, porous, and non-porous. The phenomenon of softening by base-exchange has been fairly well established as being largely a surface action. The greater therefore the area of zeolite surface exposed to the water, the more effective will be the softening. Maximum surface area may be obtained by use of small size particles or of material containing channels or passages of relatively large surface areas. These two properties constitute the major differences in the various grades of zeolite material used for water softening purposes. Equipment used is similar in appearance to a pressure filter but the operation is different. Base-exchange mineral is contained in a steel tank supported on a gravel bed beneath which is the underdraining system. Practically all softeners sold at present operate under pressure. They are operated for a given length of time, then cut out of service and backwashed with clean water. Sodium chloride solution is then run into softener and allowed to remain in

contact with the zeolite for some time. Unit is then drained and washed with enough clean water to flush out excess salt. It is then ready again for service. **7. Where Zeolites Fit In.** Power, **64:** 7, 236, August 17, 1926. To be softened by zeolite, water should be practically free from suspended solids. Free mineral acid and appreciable amounts of free carbon dioxide are also objectionable. By "zero hardness" of water is meant that not enough calcium and magnesium are present to indicate hardness as measured by standard soap solution. Zeolite softened water usually does contain some calcium and magnesium, small amounts of which are unobjectionable. Increase in evaporation due to scale prevention effected by softening is frequently quite marked. Cost of operation of zeolite softeners is affected mainly by three factors: (a) hardness of raw water; (b) cost of salt; and (c) efficiency of system. Other items of cost that enter are more or less uniform at different installations. Cost to Spring Garden plant of the Consolidated Gas, Electric Light and Power Company, of Baltimore was four cents per 1000 gallons of water treated, or 1.33 cents per grain of hardness removed per thousand gallons of water treated. A cold lime-soda softener will reduce hardness to from three to five grains and a hot softener to from one to three grains. Zeolite system may completely eliminate hardness or reduce it to from 1 to 1½ grains. Chemical precipitation softeners of continuous type may be operated constantly while majority of base-exchange softeners must be cut out for periods of from four to eight hours for reconditioning. Some zeolites may, however, be regenerated instantaneously. Some systems installed are a combination of chemical precipitation and zeolite softeners. In these, carbonate hardness is mainly removed by precipitation with lime following which zeolites are employed to eliminate residual carbonate and non-carbonate (sulphate) hardness. They must be worked cold since base-exchange mineral disintegrates in hot water. Author sums up a number of specific advantages and disadvantages of zeolite softeners. **8. Boiler Compounds.** Power, **64:** 8, 279, August 24, 1926. Variety and composition of substances employed for internal treatment of boiler is great. Some are inefficient, others have caused damage to boilers, and some possess merit. Indiscriminate dosing of feed water with chemicals cannot be too strongly condemned. Treatment within boilers does not eliminate ingredients from the water but it may so change them as to prevent scale-forming, foaming, or corrosion tendencies; the solids in the boiler must be removed by blowing down. Under the supervision of trained operators, some relatively large boiler installations are employing internal treatment successfully. Internal treatment may be divided into two main classes: (1) controlling deposition of scale-forming solids by use of sodium salts, so as to precipitate calcium and magnesium as sludge which may be blown from the boiler; (2) adding compounds which prevent formation of adherent crystalline scale or prevent corrosion, priming and foaming. Boiler compounds offered for sale under various trade names, may be classified under one of the following groups: (a) sodium compounds; (b) sodium compound mixed with organic substances, usually some form of tannin; (c) organic substances without tannin; (d) barium compounds and compounds containing castor oil (antifoaming); (e) mechanically acting compounds; (f) inert materials. Author reports

analyses of a number of compounds. Claims have been advanced that graphite will remove old scale and prevent scale formation. Graphite may remove scale under some conditions but reliable information indicates that it may be a highly corrosive agent when used in steam boilers. In the anti-foaming class of boiler compounds castor oil is used extensively, and barium salts, occasionally. Cost of boiler compounds may or may not be less than that of operating water-softening system, depending upon price paid for compound, amount used, and efficiency of the treatment. In most cases where boiler compounds are used to advantage, the treatment is applied by intelligent operators and controlled by analyses of the raw and treated water.—*Aug. G. Nolte.*

Modern Methods in Coal and Ash Handling. W. W. SAYERS. Power, **64:** 4, 133, July 27, 1926. Trend of progress in coal and ash handling methods and equipment is discussed. Author reviews conditions that obtained not so long ago and shows how economic trend has influenced change in equipment.—*Aug. G. Nolte.*

Cochrane Improved Pressure Filter. Power, **64:** 4, 145, July 27, 1926. Construction of this filter is described.—*Aug. G. Nolte.*

Elevators and Conveyors for Coal Handling. W. W. SAYERS. Power, **64:** 5, 169, August 3, 1926. Review of the different types of equipment is given and conditions governing the selection and application of various types are discussed.—*Aug. G. Nolte.*

How to Lay Out Power-Plant Piping. S. CROCKER. Power, **64:** 5, 172, August 3, 1926. Calculations of expansion stresses are discussed.—*Aug. G. Nolte.*

Belt Conveyors and Skip Hoists. W. W. SAYERS. Power, **64:** 6, 204, August 10, 1926. Belt conveyors for handling coal, types of idler used, and capacity range are discussed. Various uses of the skip hoist are explained.—*Aug. G. Nolte.*

Bucket Conveyors and Storage Equipment. W. W. SAYERS. Power, **64:** 7, 240, August 17, 1926. Pivoted-bucket carrier, in many installations, is found economical. Hoisting towers provided with grab buckets are used for elevating and discharging coal into overhead hoppers for distribution. Various equipments for storage are in use. Where space is limited portable types of elevator and conveyor are used extensively. At some plants locomotive cranes provided with grab buckets are found. For larger installations the "circular store system" is used to advantage. Bridge tramways are sometimes used for unloading and storing water-borne coal. Power hoe or drag scraper is well suited for irregular ground areas.—*Aug. G. Nolte.*

Suggested Rules for the Care of Power Boilers. Power, **62:** 6, 224, August 11, 1925. Proposed as an addition to the A. S. M. E. Boiler Construction

Code. Rules treat of feed-water analysis, treatment, and control as follows, (1) Work in laboratory; (2) Quick laboratory test for determining the soda treatment for a raw water; (3) Chemical control in the field; (4) Check tests in the field: with raw water; with treated water; with blowdown water; and with condensate and trap discharges.—*Aug. G. Nolte.*

Storing Coal by Packing It Down. Power, 62: 7, 237, August 18, 1925. Philadelphia Electric Company, in order to eliminate spontaneous combustion of coal in storage, has devised effective method of storing. In preparing storage space, ground is covered with ash or dry earth and then rolled hard. On this foundation successive two-foot layers of coal are spread and rolled with tractor and roller. This is continued upward until top of pile is only as wide as tractor and roller. In this manner coal is so compacted as to weigh 65 pounds per cubic foot instead of 45 or 50 pounds. Pile sheds water and in all probability circulation of air is entirely eliminated.—*Aug. G. Nolte.*

Direct-Current Motors Fail to Start—Open Circuits. B. A. Briggs. Power, 62: 7, 242, August 18, 1925. Diagnosing the trouble. Methods of testing fuses and circuits are discussed.—*Aug. G. Nolte.*

Rewinding Direct-Current Armatures. Frank Huskinson. Power, 62: 9, 321, September 1, 1925. Author enumerates and explains the different steps in rewinding an armature.—*Aug. G. Nolte.*

Questions and Answers. Franklin van Winkle. Subjects as follow, Power, 62: 6, 220, August 11, 1925. Locating Air Leaks in Boiler Setting; Suction Lift Less than Height Corresponding to Atmospheric Pressure; Proximate Analysis of Coal; Locating Faults in Field Coils; Action of Inertia Governor. 62: 7, 260, August 18, 1925. Laps and Rivet Pitches of Girth Seams; Resetting Eccentric on D Slide-Valve Engine; Irregular Division of Draft Between Boilers; Heat Recoverable from Exhaust of Diesel Engines; Water Required for Jet Condenser; Power Saved from Reduction of Head Pressure of Ammonia Compressor. 62: 8, 302, August 25, 1925. Trouble with Hvid Engine; Refrigeration Capacity for Cooling Air; Running Engine Over or Under; Lap of Steam Valves of Duplex Pump; Reduction of Air Pressure for Air Lift; Connections for Pumps Operating in Parallel; Comparison of Diesel and Steam Engine Indicator Diagrams; Required Pipe Size for Given Steam Velocity. 62: 9, 341, September 1, 1925. Cutting Glass Tubing; Safe Working Pressure for H. R. T. Boiler; Inches of Pressure; Power for Pumping Lost in Pipe Friction; Inside and Outside Fusible Plugs; Slower Speed for Lower Initial Pressure; Reasons for Excessive Back Pressure; Advantages of Operating Condensing; Supplementing Exhaust with Live Steam. 62: 10, 379, September 8, 1925. Checking Height of Glass Water Gage; Knock in Duplex Boiler-Feed Pump; Soap and Water for Cleansing Cylinders of Air Compressors; Removing Scale from Water Jacket; Interchanging Crosshead Shoes; Size of Exhaust Main for Several Exhaust Branches; Reducing Discharge Temperature of Ammonia Compressor; Over-Rated Performance of Boiler; Setting Eccentric for Given Lap and Lead.—*Aug. G. Nolte.*

Report of the Department of Public Utilities, City of Cleveland—1925. Division of Water and Heat. Water from Lake Erie, treated and filtered, is supplied to the inhabitants of twenty-five individual political sub-divisions and ten additional governmental units inside the county sewer districts. Area includes Cleveland—70 square miles, and adjacent territory of 164 square miles. In 1925 the actual pumpage of water from Lake Erie was 7 billion, 942 million cubic feet. Amount of water sold was 5 billion, 933 million, 346 thousand cubic feet. Enactment of Griswold Law (effective January, 1922) reduced water works bonds to a 25 year serial basis, thereby compelling the Department to finance assets of long life (25–50 and even 100 years) with serial bonds which in reality have an average life of only 12 to 15 years. Increased debt charges in 1923–24 and 25, resulting from serial bonds issued since January, 1922, as compared with 50 year term bonds, is $725,000. Extensions and proposed increased water rates are given.—*A. W. Blohm.*

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